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September 2007

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What lurks between GALAXIES?

Powerful secrets lie scattered
throughout the universe's darkness p. 28

**How Carnegie
astronomers hunt
dark energy** p. 34

PLUS:

Inside Timothy Ferris' new film
Seeing in the Dark p. 82

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How to visit an observatory p. 78

Steve O'Meara on the lady in the Moon p. 18

Rich galaxy clusters like
Cl 0024+17 may appear
to rule the cosmos, but
the near-empty voids
between clusters fill
much more space.



**ALL ABOUT THE
DUMBBELL
NEBULA** p. 68

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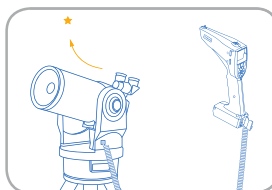
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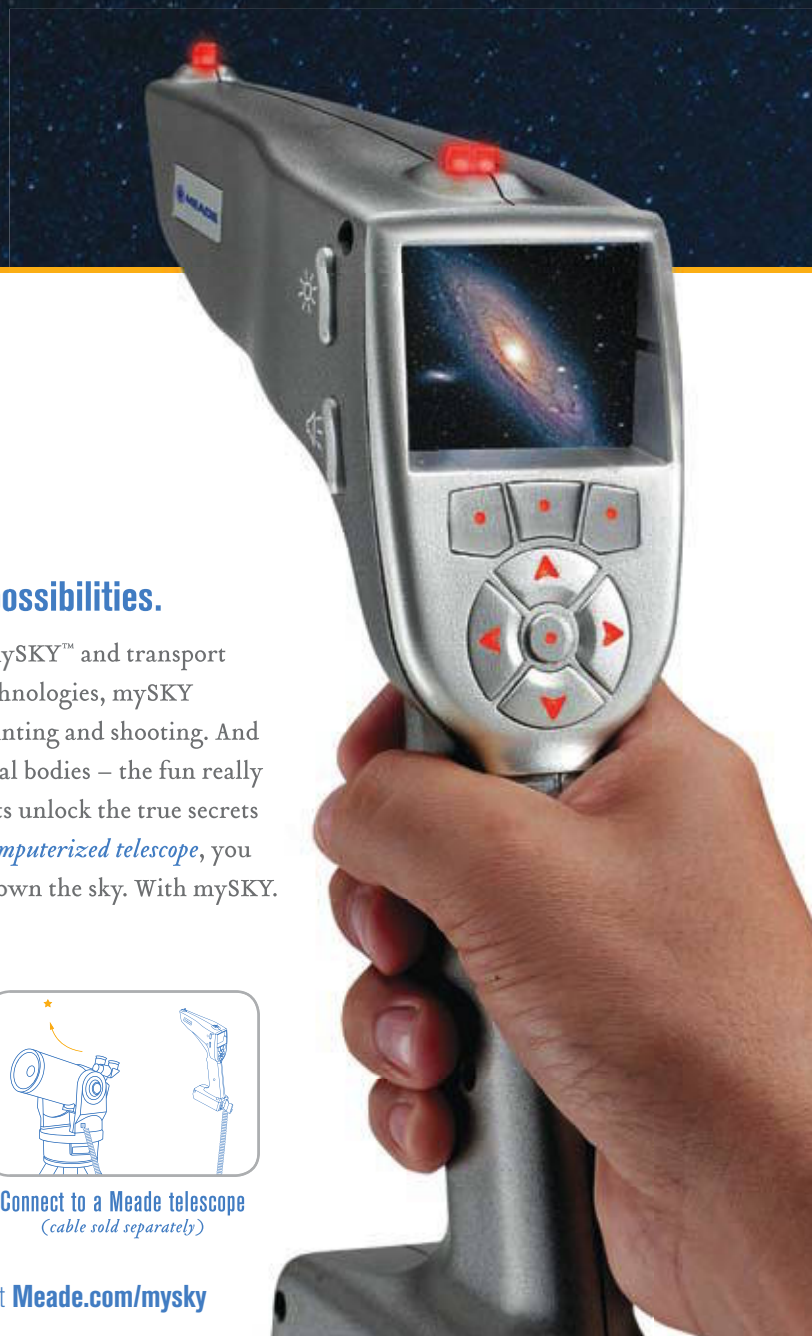


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Astronomy

VOL. 35, NO. 9

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What lurks between galaxies?

An ever-expanding portion of the cosmos contains virtually nothing, but what little there is may tell astronomers how galaxies formed and evolved. **BRUCE DORMINEY**

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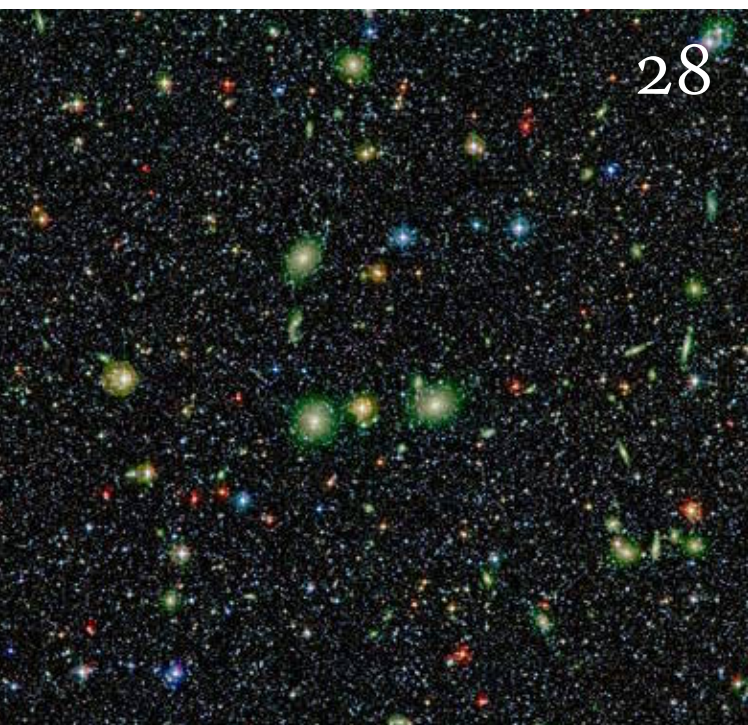
Bob Berman goes behind the scenes at Carnegie Observatories to get the scoop on an unprecedented survey of exploding stars. **BOB BERMAN**

ONLINE EXTRA: Director Wendy Freedman talks about the future.

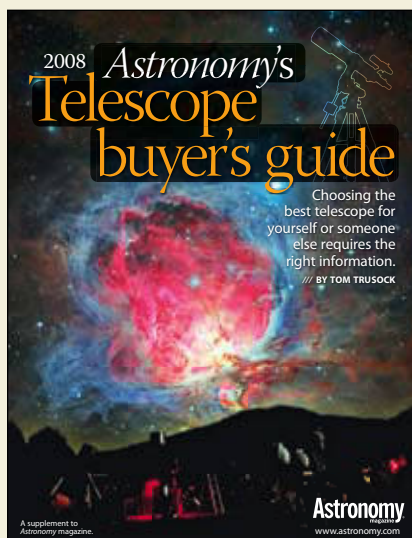
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MARTIN RATCLIFFE AND ALISTER LING



ASTRONOMY: ROBIN KELLY; TELESCOPES: CARNEGIE OBSERVATORIES; GALAXY: ADAM BLOCK/NOAO/AURA/NSF



EXCLUSIVE PULLOUT Astronomy's 2008 telescope buyer's guide



Are you in the market for a new telescope? Start here. Our buyer's guide gives you the lowdown on 39 refractors, reflectors, and compound scopes starting at just \$200.

Whatever you're looking for, you'll find it here.

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Why it's hard to believe in dark energy

I don't think any of us has really gotten over the initial announcement yet. In 1998, two teams of astronomers announced we know virtually nothing about 70 percent or more of the universe. They told us this percentage of the cosmos exists in the form of a mysterious "dark

energy." We have been in a state of collective bewilderment over this idea ever since.

We know the concept of dark energy is likely correct. The evidence comes from two parallel research teams: the High-Z Supernova Search Team and the Supernova Cosmology Project (SCP). Adam Riess of the Space Telescope Science Institute and his High-Z Team colleagues discovered the universe's expansion is accelerating as measured by studying the light from supernovae at different distances from Earth. The same year, Saul Perlmutter of the University of California-Berkeley and the SCP team confirmed the observations.

Explanations for the accelerating universe are few. Either the expansion of the universe is accelerating, meaning some kind of energy or force is the cause; or general relativity is wrong; or the supernova observations are flawed. The last two options appear highly unlikely. The first, the existence of a previously unknown force in the cosmos, seems correct. Also in 1998, Michael Turner of the University of Chicago named this force "dark energy."

In any business, it's a little unsettling to know almost nothing about 70 percent of your field of study. Scores of astronomers are now working on these questions: Exactly what is dark energy? How did it arise? What will it tell us about the origin and fate of the universe?

Riess, Perlmutter, and the full teams of the High-Z and SCP collaborations are

going full-speed ahead. Launched in 2004, the Carnegie Supernova Project is another battlefield in the war to understand. To write about Carnegie's search for dark energy, *Astronomy* Contributing Editor Bob Berman traveled to Chile's Atacama Desert to visit the Las Campanas Observatory. His story of the excursion and the science carried out at Carnegie Observatories appears in "Will supernovae shine new light on dark energy?" (page 34).

I'm sure you enjoy Berman's column, "Bob Berman's strange universe." No doubt you'll also relish his story of the science conducted at Carnegie. At Las Campanas, Gaston Folatelli, a young Argentinean postdoc, introduced Berman to the Supernova Project. Also at Las Campanas, astronomers Barry Madore and Wendy Freedman, husband and wife, search for supernovae in distant galaxies near the limiting grasp of the Carnegie telescopes.

The story is one of science as it happens every day, in dribbles of data, little events in a big place, with the promise of huge results looming in the not-too-distant future.

Yours truly,

David J. Eicher
Editor

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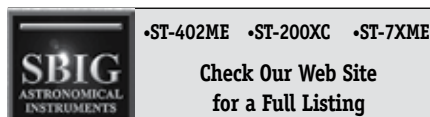
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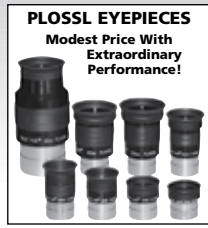
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A newsworthy image

I enjoy receiving regular e-mails from *Astronomy*. I was delighted to see Hubble's new Eta Carinae Nebula image. I went so far as to seek higher-resolution images on Hubble's web site (hubblesite.org) to explore the image more. ☾ Thanks for your hard work and unceasing dedication to providing the latest

astronomy news. — **BEN HODGSON**, RALEIGH, NORTH CAROLINA

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Right-on research

Many thanks for your excellent article on Eta Carinae ("The supernova next door," June 2007). But you didn't stress how truly unique the observational background is!

Most of the discoveries you described were based on the Hubble Treasury Project for Eta Car (see etacar.umn.edu). In my opinion, this is the most intensive spectroscopic program ever done with the Hubble Space Telescope (HST).

HST's technical capabilities are almost perfectly adapted to Eta Car's problems. A particular set of observations, all done on one day, led to several of the discoveries that you mentioned: Eta's peanut-shaped wind, the clearest information on the Little Homunculus, the first real proof of flat equatorial debris, and the first good cross section of the Homunculus. This may have set a record for HST research efficiency!

I was the principal investigator for the Treasury Project and most of the earlier HST Eta Carinae programs. In addition



HUBBLE'S IMAGE of the colorful Eta Carinae Nebula shows both star birth and death. NASA/ESA/N. SMITH (UC-BERKELEY)/AND THE HUBBLE HERITAGE TEAM (STScI/AURA)

to the people you mentioned, other particularly active co-investigators were Ted Gull at NASA's Goddard Space Flight Center and D. J. Hillier at the University of Pittsburgh. — **KRIS DAVIDSON**, ASTRONOMY DEPT., UNIVERSITY OF MINNESOTA

Online videos

"Astronomy update" videos online [Astronomy.com/videos] are outstanding and a tremendous help to us novices. I am an armchair astronomer because of eyesight problems. Reading print is also difficult, so I rely on pictures and television to explain the universe.

Your new feature will go a long way in helping explain all the great mysteries out there. — **THOMAS DOUGHERTY**, LAS VEGAS

Reader tips

After years of growing frustration, I figured out how to move my Dob smoothly.

I drilled two holes through the box holding the scope just above the bottom of the box and ran a 2-foot-long dowel through the holes. I tied a string to the bottom of the scope and wound the string onto the dowel. By turning the dowel rod, I slowly crank the base down, raising the scope's elevation.

To decrease elevation, I have an arm with a pulley above the scope's base. I threaded the string from the base of the scope through the pulley on the arm to the dowel.

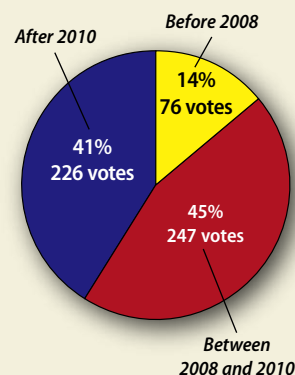
For left and right adjustments, I drove small nails in an 18-inch circle in the scope base. Then, I drove in a large screw an inch above the base horizontally into the box holding the scope (which rotates on the base). By using a 12-inch flat screwdriver, I can smoothly pry the scope box in either direction.

— **LEWIS BRACKETT**, SAN DIEGO

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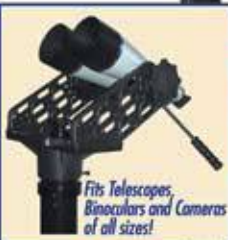
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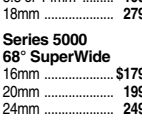


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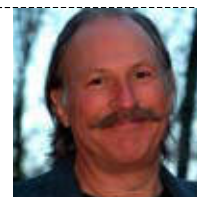
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Forging massive stars

With fanciful nicknames like “Skull and Crossbones” and the “Celestial Mandrill,” the region surrounding open star cluster NGC 2467 has a lot to live up to. It doesn’t disappoint. For the past few million years, this area in Puppis the Stern has been spitting out hot, brilliant stars, igniting the surrounding cloud of gas and dust to incandescence. NGC 2467 lies in the “Puppis Window” — an area in our galaxy’s plane marked by unusually low interstellar absorption — which gives astronomers a clear view of the cluster despite its 20,000-light-year distance. The brightest stars embedded in the nebulosity radiate a million times more energy than the Sun.  ESO







For sale: the equator

I visited the enormous monument built on the “equator” near Quito, Ecuador, a few months ago. The area surrounding “Mitad del Mundo” offers a bustling scene with commercial shops, earsplitting bands, and a huge obelisk from which a line on the ground extends a long distance.

Tourists get their pictures taken with one foot in the “Northern Hemisphere” and the other across the line in the “southern.” Great fun, except, it’s not the equator.

Another supposed equator sits a quarter-mile north. Leaving the fancy official government monument and walking a few minutes up the highway, you get to a dirt road that leads to the Inti Nan Solar Museum, which has its own equator line. This museum’s lecturers claim to have the true equator, based on GPS measurements.

So our planet has competing equators. Each attracts many visitors. And listen to this: I got the Inti Nan director to admit that the real honest-to-goodness equator is in neither place, but another 50 yards (45 meters) further north on vacant land. If you’re looking for a business opportunity, buy this parcel and set up a third equator exhibit. The crowds seem big enough to support more of them.

Alas, Earth’s poles keep migrating in a pivot known as the Chandler Wobble. Because the poles roam as much as a football field, so does the equator. Tourists want a narrow line they can straddle, but an accurate, permanent equator exhibit would require a swath of land the width of an interstate highway, to be sure the coveted line lies somewhere in that space.

Anyway, the museum had nonstop demonstrations, most of which were ridiculous. A lecturer pulls a plug in a basin, and the crowd watches water spiral down the drain. Then she moves the basin a few feet across the dubious equator line, pours in the water again, pulls the plug and, sure enough, now

the water spirals down the opposite way. The crowds enthusiastically lap this up — figuratively, of course. I asked, “May I do this demonstration myself?” The lecturer took me aside and quietly advised, “Okay, but you have to pour the water the correct way. Do it from the right when on this side of the line, then pour it in from the other side of the basin, when on the south side. That’s the only way to make the water swirl down the way we want it to go.”

**SUFFICE IT TO SAY,
it’s fun being on the
equator, even if science
struggles to prevail there.**

In other words, they know they’re faking the whole thing. She lamely explained, “We do say it’s just a demonstration.”

They also have a sign announcing that your body weighs a kilogram less at the equator because Earth’s bulge makes you stand farther from our core, reducing the effect of gravity. Even the director didn’t know that the weight loss, which incidentally is only a quarter of what they claim, has nothing to do with our planet’s bulge. It has everything to do with greater rotation speed at the equator, which throws us slightly outward, like a carnival ride.

I could talk about their balancing an egg on a nail and other stuff, which reaches a frenzy during the equinox this month, when the Sun is straight over those monuments. Suffice it to say, it’s fun being on the equator, even if science struggles to prevail there.

Every planet has its own equator, which stands directly beneath the Sun during that world’s equinoxes. That’s also when its equator pretty much aims our way, too.

Mercury is the only planet whose equinox lasts forever, because that charbroiled planet has no tilt. Venus’ equator is highly tilted, which would normally create wild seasons but doesn’t on Venus because the thick, suffocating air spreads the deadly heat around evenly.

Mars has a tilt like our own, and so does Saturn. These two worlds show stunning features when their equators aim toward the Sun and Earth. The martian equinox is happening now, which means both poles are presented equally well, although the northern pole has just finished its winter and therefore displays much more ice. Check it out, especially this December during Mars’ Christmas Eve opposition.

Saturn’s equinox, coming up in 2009, will cause its rings to move dramatically edgewise and vanish through backyard scopes.

Jupiter’s equator tilts only 3°, which is why its four major moons, orbiting the equator, always form a straight line, more or less.

Uranus’ equinox is happening now in 2007, for the first time in 42 years. With its rings edgewise, Uranus’ ultra-tipped equator lies up and down, and its moons rise and fall like elevators from our viewpoint.

In other words, equators and equinoxes are special everywhere. They look cool and obvious through backyard telescopes.

Now, back to my get-rich-quick scheme to set up a weight-loss clinic at the equator and guarantee instant results. We could even serve balanced eggs: Sunny side up, now at the equinox. ■

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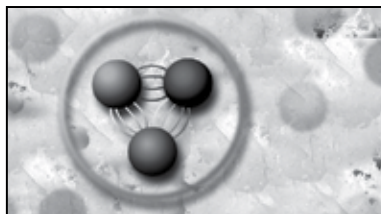
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Model of protons showing quarks

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About Your Professor

Dr. Steven Pollock (Ph.D., Stanford University) is Associate Professor of Physics at the University of Colorado at Boulder. He has taught physics courses from introductory physics to advanced nuclear and particle physics. He received the Boulder Faculty Assembly Teaching Excellence Award in 1998. He became a Pew/Carnegie National Teaching Scholar in 2001. He is the author of *Thinkwell's Physics I*, a CD-based textbook.

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An asterism by any other name

Last year, I described an eye-catching group of double stars I first found in 1972. While searching with a 3-inch reflector for the double star h1470, I stumbled upon this collection a degree northeast of 25 Cygni. To my surprise and delight, h1470 was in the company of three

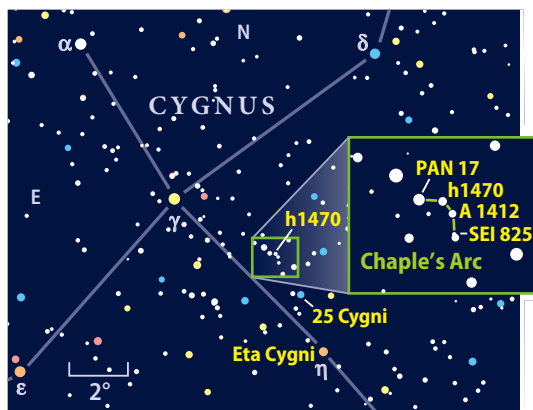
similar-looking pairs — all arranged in an arc less than a half degree across.

After reading my account in the September 1980 issue of *Deep Sky Monthly*, New York amateur astronomer John Pazmino observed the quartet and dubbed it “Chaple’s Arc.” I revisited this little asterism in this column last September.

Several *Astronomy* readers observed the Arc and forwarded their impressions. Bill Pellerin of Houston described its appearance in his 70mm refractor at 68x: “The stars are rather dim, and it was difficult for me to see all four doubles with such a small telescope. The small curve of stars is duplicated by another nearby arc of dimmer stars, which could lead you to believe that your scope is playing tricks on you.”

Don Judd of Midland, Texas, asked me to identify the four double stars that comprise the Arc. According to the *Washington Double Star Catalog*, the doubles are, from west to east, **SEI 825** (magnitudes 10.0 and 10.8, separation 6.9”), **A 1412** (9.0 and 9.3, 0.8”), **h1470** (7.4 and 9.2, 28.6”), and **PAN 17** (8.3 and 11.4, 16.6”). Only h1470 is a “true” cataloged double star; the two stars we see with small telescopes are the actual pair. Of the remaining three doubles, either the primary or secondary star is the cataloged pair.

An e-mail from Fred Kaullen of Bay, Arkansas, indicated others had independently discovered the Arc. “I always wondered if there was a name for that asterism.



LOCATING CHAPLE'S ARC is a terrific challenge for beginning telescope observers. Begin with Eta (η) Cygni, hop to 25 Cygni, then rest on h1470 — the double with the brightest components in this asterism. ASTRONOMY: ROEN KELLY

I saw the quadruple double, or ‘Eight-Pack,’ as we called it at the time, around 1988 while scanning Cygnus with an 8-inch Schmidt-Cassegrain and 55mm Plössl in the mountains outside of San Diego. The sight was glorious.”

Kaullen wasn’t the only co-discoverer. In 2006, I came upon a short article in a British astronomy magazine about an asterism in Cygnus called the “Fairy Ring.” The accompanying finder chart and sketch left no doubt — the Fairy Ring was identical to my Arc!

Doing a little detective work, I learned that in the early 1990s, Utah amateur astronomer Kim Hyatt independently

found the asterism. Like me, he had been looking for h1470. Using a 10-inch reflector, Hyatt perceived several fainter pairs that, with the Arc, form a ghostly ring. He christened this find the Fairy Ring asterism and reported it to his friend Brent Watson. Watson included the Fairy Ring in the

booklet *Finder Charts of Overlooked Objects* (Sky Spot, 1992). His description reads, “This object is a beautiful happenstance grouping of six moderately wide double stars arranged more or less in a ring, then a wide pair in the center ... This asterism is an interesting change from the usual deep-sky observing in which many amateurs engage.” For more information on Watson’s booklet, visit www.sky-spot.com.

Whether you call it Chaple’s Arc, the Eight-Pack, or the Fairy Ring, this double-star group is an amazing sight for late summer observing.

How did you do?

Here are the answers to last month’s sky-distance challenge. The distances, in degrees, between the Alpha and Beta stars of the following constellations are Aquarius, 10; Aquila, 2.5; Boötes, 23; Capricornus, 2.5; Cygnus, 22; Delphinus, 1.5; Hercules, 13; Libra, 9; Lyra, 6; Ophiuchus, 8; Pegasus, 13; Scorpius, 8.5.

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com.

Next month: We’ll celebrate Sputnik’s 50th birthday! ■

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Read Chaple’s double-stars story from the September 1980 *Deep Sky Monthly* at www.astronomy.com/toc.

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The Rosette Nebula dual frame mosaic image taken with Tele Vue-NP127is and Apogee Alta U9000 CCD camera by Tim Puckett and Adam Block.

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Strum the Harp

The brilliant stellar sapphire Vega

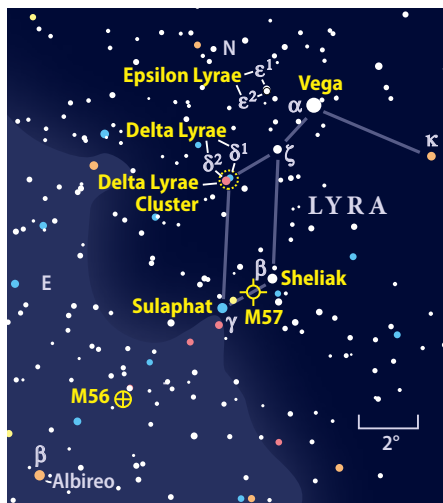
(Alpha [α] Lyrae) sparkles high in the west this month. Famous as the fifth-brightest star in the night sky, Vega's dazzling glow punches through even severe light pollution. You simply can't miss it! ☞ The next chance you get, take a look

at Vega through your binoculars. As you enjoy its blue-white luster, consider that the light you are seeing left there 25 years ago. Even though that works out to be 147 trillion miles (237 trillion kilometers), Vega is just a "town" or two away on the cosmic distance scale. We're practically neighbors.

Lyra, Vega's constellation, symbolizes the lyre, or harp, owned by the mythological musician Orpheus. Vega marks a portion of the harp's handle, while four fainter stars in a parallelogram frame its body. Light pollution may hide those four stars, so if you can't make them out by eye, use your binoculars instead. Each is worth a closer look.

For instance, **Sheliak** (Beta [β] Lyrae), at the parallelogram's southwestern corner, is more than a faint star. Sheliak is actually an eclipsing binary that is perfect for binocular study. In just under 13 days, an unseen companion star causes Sheliak to flicker from magnitude 3.3 to 4.3. Compare Sheliak's brightness to that of nearby stars that do not vary to confirm its 13-day cycle. This month, you'll find a chart at www.astronomy.com/toc for tracking Sheliak's changing appearance.

The most photographed planetary nebula of all, the **Ring Nebula** (M57), lies along the southern edge of the harp's parallelogram. To spot it, look midway between Sheliak and **Sulaphat** (Gamma [γ] Lyrae) for three faint stars that create a tiny right triangle. The "star" at the right angle is actually the Ring. Although it takes at least 50x to make out its classic smoke-ring shape, I've seen M57 as a faint starlike point through binoculars as small



WHILE TOURING LYRA with binoculars, take time for a double-star challenge: Separate the doubles Delta and Epsilon Lyrae. ASTRONOMY: ROEN KELLY

as 7x35. Give this challenge a try tonight, and let me know if you are successful. I would be interested in finding out the smallest binoculars that will uncover M57. E-mail your observations to me at phil@philharrington.net or share them with other readers on *Astronomy's* message board at www.astronomy.com/forums.

Now, scan southeast of Sulaphat, toward the star Albireo (Beta [β] Cygni), and pause about halfway in between. There, you'll find a conspicuous asterism shaped like the number 7. If you look just to the 7's south-east, you should spot a smudge that doesn't quite look like a star. That's globular cluster **M56**. Although 100,000 stars make up the cluster, M56 is too far away to resolve

through binoculars. That feat requires at least a 6-inch telescope.

Even the smallest pocket binoculars, however, will reveal **Delta (δ) Lyrae**, at the Harp's northeastern corner, as two close-set stars. In fact, some sharp-eyed stargazers don't need any optical aid at all to see them. The pair's brighter star, magnitude 4.3 Delta², looks orangish, while magnitude 5.6 Delta¹ is bluish-white.

The two Delta stars belong to a scattered open cluster nicknamed the **Delta Lyrae Cluster** and cataloged as Stephenson 1. Fifteen stars belong to Stephenson 1, with most too faint for binoculars. Although both Deltas belong to this cluster, studies suggest that Delta¹ lies about 1,200 light-years away, while Delta² rests about 200 light-years closer to us — a classic example of an optical binary star.

The last stop on our tour is **Epsilon (ε) Lyrae**, just to Vega's northeast. If you have acute vision, you may also be able to split Epsilon into two stars by naked eye alone. The stars are separated by 3.5', which is near the naked eye's resolution limit. Of course, through binoculars, Epsilon easily resolves into two points of light. The northernmost of the pair is labeled Epsilon¹, while the other is Epsilon².

Many observers also know this system as the Double Double, because Epsilon¹ and Epsilon² are each close-set pairs of stars. Unfortunately, it takes at least 80x magnification to see all four Epsilon affiliates. Although we can see only two stars, the added beauty of gleaming Vega to the southwest and Zeta (ζ) Lyrae to the southeast create a stunning binocular scene.

Next month, we'll head south into a "wet part" of the autumn sky. Until then, remember, two eyes are better than one. ☞

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Find out more about Zeta Lyrae and two variable stars in Lyra at www.astronomy.com/toc.

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The Moon shows “her” true colors

What have you got in your knapsack
fair / White moon, bright moon, pearling the air / Spinning
your bobbins and fabrics free / Fleet moon, sweet moon, in to
the sea? / Turquoise and beryl and rings of gold / Clear moon,
dear moon, ne’er to be sold? — Zora Bernice May Cross

When Australian poet Zora Bernice May Cross (1890–1964) penned this verse for her poem “The New Moon,” she captured the spectral purity of our planet’s nearest neighbor. Her inspiration for the third verse may have come from an old Vedic hymn that urges the Full Moon to work with a needle to sew her luminous garments: a silver one for the evening and a gold one for the day. What’s beautiful about this stanza is that the woman in the Moon, her colored garments, jewelry, and sewing needle, are more than poetic metaphors. Cross, whether she knew it or not, shares one of the Moon’s greatest secrets: It’s a fanciful world of imagined features and subtle color — visible wonders within the grasp of any binocular observer.

AN APOGEE MOON

posed for this false-color view. The photographer processed the RGB image to showcase the lunar surface’s geology. The dark blue indicates the presence of titanium and titanium-oxide, while orange designates regions of aluminum and iron.

ANTHONY AVIOMAMITIS

Lady Moon

Let’s start with the most obvious, although often overlooked, feature: the “woman” in the Moon. Like her male counterpart, the woman, or lady, in the Moon, is a romantic arrangement of bright lunar highlands and dark maria. When combined, these features

appear as a lady’s head and neck in profile. Five dark maria — Serenitatis, Tranquillitatis, Foecunditatis, Nectaris, and Crisium — fashion the woman’s hair, while the bright spot between Mare Tranquillitatis, Fecunditatis, and Nectaris, is a plump hibiscus flower. Mare Vaporum marks her eye, and Sinus Medii forms the lady’s mouth.

The woman also wears a curious pearl necklace: To the unaided eye, the pearl is a feature known as Cassini’s Bright Spot. However, through binoculars, the bright, nearby crater Tycho — invisible to the unaided eye — takes its place. Two bright diaphanous rays radiating from Tycho comprise the necklace. Overall, I think the woman looks uncannily like the profile of

Lucy Van Pelt — that lovable *Peanuts* cartoon character who’s the antagonistic friend of Charlie Brown.

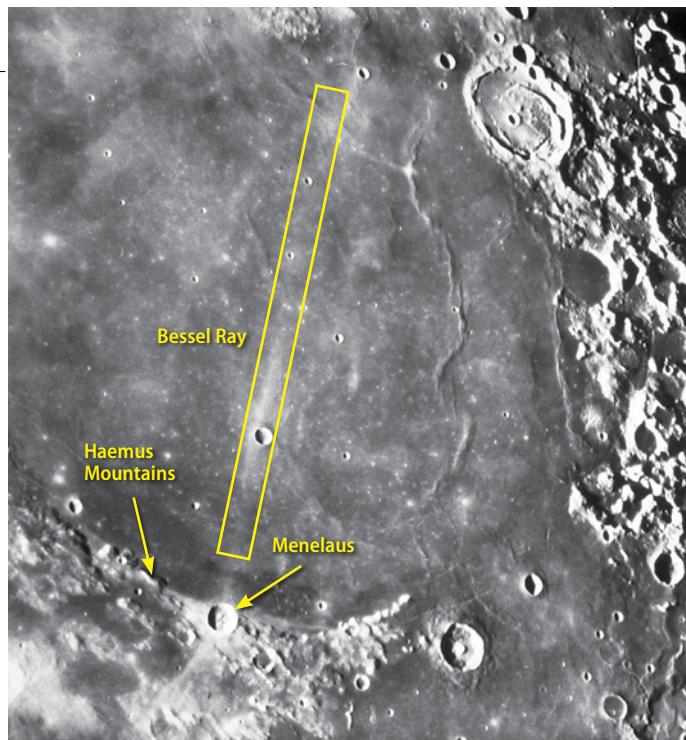
Lucy really stands out through binoculars. But therein lies the rub. Anyone who’s looked at the Full Moon through binoculars in the dark of the night can attest to the shocking blast of light that will ruin your night vision. Most people who do look react immediately and impulsively by turning away, as if the Moon had just blasted sand into their eyes. But it’s that natural impulse to look away that prevents us from fully enjoying one of the most delicate sights in the heavens — color on the Moon.



The woman in the Moon



THE WOMAN IN THE MOON attained her profile from a collection of maria: (1) Sinus Medii, (2) Mare Vaporum, (3) Mare Serenitatis, (4) Mare Tranquillitatis, (5) Mare Crisium, (6) Mare Fecunditatis, and (7) Mare Nectaris. Aim your binoculars at her during the next Full Moon. At first, the blinding glare will feel overpowering, but gradually your eyes' cone cells will adapt. LICK OBSERVATORY



BESSEL RAY is a bright lunar feature slicing across Mare Serenitatis. Although a mystery surrounds this streak's origin, the ray is an obvious signpost pointing moonwatchers to a pocket of color. Follow Bessel Ray south, to the area containing the crater Menelaus and the Haemus Mountains. Instead of gray, patient observers may identify shades of turquoise. CONSOLIDATED LUNAR ATLAS (UA/LPI)

Hair coloring

During the next Full Moon night, go outside and train your binoculars on the Moon. Withstand the initial shock of light, hold your ground and do not look away. Continue to stare directly at the Moon, and let your eyes' day-sensitive cone cells adapt to the light. At first, this sounds strange because it's the reverse of how we usually observe at night. Imagine, however, walking out of a darkened movie theater and into a brightly lit lobby. Initially, the glare is blinding, because the pigment in your rod cells bleach out and render your night vision useless. But soon — and relatively quickly — your cone cells take over and help you see in comfort.

Richard L. Gregory explains the situation in his book *Eye and Brain: The Psychology of Seeing*: "Brightness is a function not only of the intensity of light falling on a given region of the retina at a certain time; but also of the intensity of the light that the retina has been subject to in the recent past, and of the intensities of light falling on other regions of the retina." To cut down on

the initial shock, I usually plan ahead and turn on some outside lights before I look up.

Once you light-adapt, concentrate your attention on the boundary between the smooth plains of Mare Serenitatis and the Haemus Mountains to the south, especially near the bright crater Menelaus. While it's true some maria appear as somber shades of gray, a close inspection of this region will reveal subtle shades of turquoise. The blue washes into Mare Tranquillitatis through a massive breach in the Serenitatis rim.

Carefully compare the color of Mare Tranquillitatis to that of Serenitatis. Take your time — the color difference should become obvious. Mare Tranquillitatis is predominantly blue, while Serenitatis basin appears dusted with gold. Mineral concentrations may contribute to this difference in coloration. Spectroscopic observations have shown, for instance, that bluer areas, contain more titanium than do the golden regions.

Look again at Mare Serenitatis. Do you see the woman's sewing "needle?" It's the mysterious Bessel Ray. This bright splash of

moondust cleanly bisects Mare Serenitatis from the northwest to the southeast, as seen against the sky. No one is certain of the ray's origin. As reported in a 1992 *Proceedings of Lunar and Planetary Science*, Bruce Campbell of the Smithsonian Institution's Center for Earth and Planetary Studies and his colleagues used radar and CCD images to study Bessel Ray. They found it is characterized by up to 40-percent highland ejecta — debris expelled following an impact from a region outside of Mare Serenitatis.

But look carefully at the ray. To me, it has a distinctly strong golden patina, stronger than that found in the diffuse heart-shaped blanket of "gold dust" surrounding it. Try comparing the color of Bessel Ray to those marks radiating from Tycho, all of which I see as shimmering white. Send me an e-mail at someara@interpac.net and let me know what you see.

By the way, French astronomer Giovanni Domenico Cassini (1625–1712) beautifully rendered the woman's needle and the heart-shaped blanket she appears to sew in his 1670 lunar map. ■

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Astron**news**



NASA/ESA/M. J. JEE AND H. FORD (JOHNS HOPKINS UNIVERSITY)

WEDDING RING. The merger of two galaxy clusters forged a unique dark-matter union. This composite Hubble image reveals a ghostly "ring" of dark matter, which is shown as blue. Astronomers mapped the dark matter by observing the distorted shapes of background galaxies.

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black hole

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Dark-matter ring comes to light

Astronomers have long known dark matter serves as the "glue" that holds together galaxy clusters. Now, Hubble researchers have found a ring of dark matter built from the dark-matter content of two merged clusters.

"This is the first time we have detected dark matter as having a unique structure that is different from both the gas and the galaxies in the cluster," says team leader M. James Jee of Johns Hopkins University in Baltimore. The discovery means

astronomers will be able to study how dark matter behaves differently from normal matter.

The team targeted the cluster Cl 0024+17, located 5 billion light-years from Earth in the constellation Pisces. Although astronomers can't see dark matter, they can infer its presence from how its gravity bends light from background galaxies.

The distorted shapes of the galaxies beyond Cl 0024+17 reveal the cluster's ring of dark matter spans 2.6 million light-

years. The ring apparently formed when two clusters collided 1 to 2 billion years ago.

"The collision created a ripple of dark matter that left distinct footprints in the shapes of background galaxies," says Jee. "It's like looking at pebbles on the bottom of a pond with surface ripples. The pebbles' shapes appear to change as the ripples pass over them." Jee's team published the discovery in the June 1 issue of *The Astrophysical Journal*. — **RICHARD TALCOTT**



NASA/JPL/SSI

TIGER STRIPES. A series of long cracks near the south pole (bottom) of Enceladus may move back and forth, and open and close, under tidal stresses from Saturn.

Enceladus all cracked up

Saturn's gravity generates strong tidal forces in the moon Enceladus, wreaking havoc on cracks in the moon's icy surface. New research suggests the cracks open and close as the moon revolves around the gas-giant planet, and friction caused by back-and-forth motion along the faults may power the moon's geysers.

The series of 75-mile-long (120 kilometers) cracks, dubbed "tiger stripes" because they resemble the cat's markings, lie near Enceladus' south pole. The stripes are warmer than their surroundings, and scientists suspect the eruptions originate there.

Because Enceladus orbits Saturn on a slightly elliptical path, tidal stresses change as the Moon revolves. A team led by Terry Hurford of NASA's Goddard Space Flight Center in Greenbelt, Maryland, developed a computer model to calculate how the changing stress affects the tiger stripes. "We found that when Enceladus is farthest from Saturn, the stresses in the region pull most of them open," says Hurford. "And when Enceladus is closest to Saturn, the stresses force most of them to close."

A second team, led by Francis Nimmo of the University of California, Santa Cruz, found friction generated as the sides of the faults rub against each other releases enough heat to sublimate ice. This process could power the geysers.

Both teams say they need more observations to prove or disprove their hypotheses. They reported their results in the May 17 issue of *Nature*. — **R. T.**

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NASA/ESA/A. SARA JEDINI (UNIV. OF FLORIDA) AND G. PIOTTO (UNIV. OF PADUA)

CLUSTER TRIPLETS. Globular cluster NGC 2808 in Carina contains more than a million stars that formed in three separate bursts — not one, as most astronomers suspected.

Globular cluster baby boom

Conventional wisdom holds that all of the Milky Way's globular clusters formed in one fell swoop at the galaxy's birth. Wisdom ain't all it's cracked up to be. Hubble Space Telescope observations of the massive cluster NGC 2808 show it experienced three bursts of star formation within its first 200 million years of existence.

"We had never imagined that anything like this could happen," says Giampaolo Piotto of Italy's University of Padua, who led the team that discovered the multiple generations. "This is a complete shock."

The astronomers found the three distinct populations by looking at the stars' brightnesses and colors. Each successive generation appears slightly bluer, suggesting a different mix of chemical elements.

Another possible explanation is that NGC 2808 may be masquerading as a globular cluster. The cluster contains more than a million stars, making it 2 to 3 times more massive than a typical globular. It could be a dwarf galaxy stripped of most of its substance when the Milky Way captured it. The team reported its findings in the May 20 issue of *The Astrophysical Journal*. — **R. T.**



Off to Mars!

If all goes as planned, NASA's Phoenix spacecraft will have lifted off in August on a 10-month journey to Mars. Once it reaches the Red Planet in May 2008, Phoenix will land in the north polar region to study the history of water and the potential habitability of the ice-rich soil.

Phoenix bears the moniker of the mythical bird "reborn in flames" for good reason. Its hardware design has risen from the dead.

A second feature Phoenix brings back to life, and just in time, is the technique of soft landing on another world by throttled rocket thrust. This hasn't been done in more than 30 years, but it will be critical for the heavy Mars rover NASA plans to land by decade's end.

The Phoenix spacecraft was built from backup hardware for the doomed 1999 Mars Polar Lander. That probe, NASA realized too late, had been built with too many shortcuts, on too tight a budget, and with too many critical reviews and tests skipped. Even before the probe reached Mars, space officials had little hope it would work.

And it didn't. It was last heard from in early December 1999, just before it entered the martian atmosphere.

Following the September 1999 loss of the Mars Climate Orbiter due to management errors, NASA initiated a hasty review of the still in-flight Mars Polar Lander. The space agency found at least one design flaw serious enough to doom the mission, and it implemented workaround procedures. But it missed a flaw in the control software that, more likely, caused the lander's crash.

MARS TOUCHDOWN. The Phoenix lander descends to the martian surface in this artist's impression. CORBY WASTE (JPL)

The flaw they fixed had to do with the thrusters getting too cold on the long cruise to Mars. The engines, adapted from a military missile, hadn't been tested at the temperatures predicted for arrival. As a result, their start-up pulses might damage the engines. To reduce this chance, mission planners turned on heaters for as long as battery power allowed, after which engineers hoped for the best.

One flaw NASA didn't fix was discovered months after the disappearance, while checking out the backup hardware that now, 8 years later, forms the basis for Phoenix. Contact sensors in the landing legs, designed to tell the engine to cut off at touchdown, also had the unintended habit of being triggered as the spring-loaded legs swung into open position after the heat shield was jettisoned. The engines would shut down prematurely, causing the craft to fall to the martian surface and crash.

Yet, if either of these failures had occurred on Polar Lander, engineers believe the probe's wreckage (and the crater it dug) would have been spotted by now. The now-defunct Mars Global Surveyor searched for the missing probe, and the Mars Reconnaissance Orbiter plans to give it a shot this year as well. This raises the haunting possibility that a different design flaw doomed Polar Lander. If so, it might still be unrecognized — and unrepaired. It will be a real nail-biter next spring when Phoenix tries to survive its landing attempt and come back to life. — **JAMES OBERG**



NASA/ESA/H. BOND (STSC)

LIGHT ECHO. In 2002, the Hubble Space Telescope imaged this suspected Luminous Red Nova (LRN) in the Milky Way. V838 Monocerotis is the red-tinged object at center; the surrounding nebosity is dust lit up by the brilliant LRN.

A new type of nova

There's a new type of object that goes bang in the cosmic night — in addition to novae, supernovae, and gamma-ray bursts. In the May 24 issue of *Nature*, a team headed by California Institute of Technology astronomer Shrinivas Kulkarni reported its discovery of a new class of stellar explosions.

The objects, which the team has dubbed Luminous Red Novae (LRNe), are brighter and redder than typical novae (nuclear explosions on the surfaces of white dwarfs), but dimmer than supernovae (exploding stars) and gamma-ray bursts.

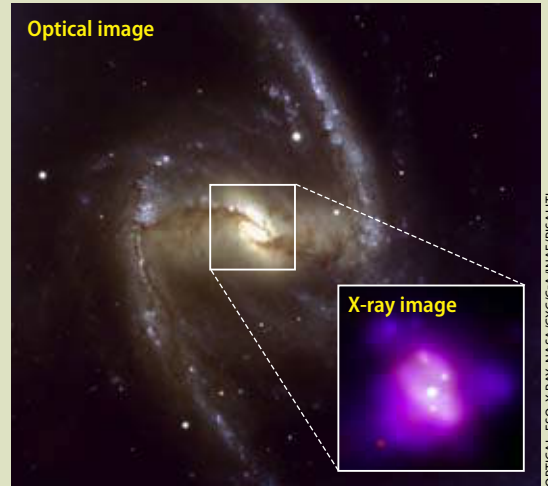
Using an automated supernova-hunting telescope at California's Lick Observatory, the team discovered the latest LRN in M85, a Virgo cluster galaxy some 60 million light-years from Earth. The star remained at peak brightness for 2 months. Kulkarni thinks the event occurred when two stars collided and merged.

The new object, named M85 OT2006-1, is the brightest and most distant of four suspected LRNe discovered since 1988. — **DANIEL PENDICK**

Sizing a hole

Astronomers have measured the size of the accretion disk surrounding the supermassive black hole at the heart of active galaxy NGC 1365. A team led by Guido Risaliti of the Harvard-Smithsonian Center for Astrophysics used the Chandra X-ray Observatory to monitor high-energy radiation streaming from the accretion disk as a dense gas cloud serendipitously eclipsed it.

The disk spans 600 million miles (1 billion kilometers), making it 10 times larger than the black hole's event horizon, the team reported in the April 20 issue of *The Astrophysical Journal Letters*. — **R. T.**



OPTICAL: ESO; X-RAY: NASA/CXC/INAF/RISALITI

ACCRETION ECLIPSE. The bright spot in the Chandra X-ray image of NGC 1365 shows a black hole's accretion disk, which spans 600 million miles (1 billion km).

BRIEFCASE

Quasar clusters

Scientists with the Sloan Digital Sky Survey have mapped more than 4,000 quasars and found these beacons clump in super-clusters separated by giant voids. The strong clustering shows the quasars lie within massive concentrations of dark matter. — **R. T.**

Making Moon dust

NASA has hired Wisconsin company Orbitec to manufacture simulated lunar dust. The space agency needs the gritty grains to make sure spacesuits and other equipment can withstand the rigors of the lunar environment. — **D. P.**

Kuiper Belt smackdown

The Kuiper Belt object 2003 EL₆₁ was nearly the size of Pluto 4.5 billion years ago, when another object rammed it. The collision left behind football-shaped 2003 EL₆₁, a couple of moons, and several fragments that flew away entirely. — **R. T.**

25 years ago in Astronomy

Science-fiction writers once envisioned Venus as a planet of steamy swamps and lush jungles. By 1982, NASA's Pioneer and the Soviet Union's Venera missions had returned evidence of a dry, volcanic planet, yet Earth's so-called twin remained mysterious.

Astronomy's September 1982 issue devoted 17 pages to Venus' history, geology, and atmosphere. Thanks to missions like Magellan and the current Venus Express, astronomers know more about the cloud-shrouded planet today, although there's still much we have to learn. And while they share similar diameters, masses, and densities, Earth and her "twin" remain worlds apart.



September 1982



September 1997

10 years ago in Astronomy

Since John Milton wrote about the possibility of life on the Moon in 1667, humans have been fascinated by the prospect of extraterrestrial life. In September 1997, scientist Seth Shostak's "When E.T. Calls Us" asked what might happen if we received radio signals from an alien civilization.

A misconception, Shostak said, is that scientists listen for "messages" from other planets. In fact, they typically tune their receivers to find steady or slowly pulsing signals, which may or may not indicate life's presence on other worlds. Could we hope to decipher a message from another planet? And if we did decipher a message, how would we — or should we — reply? Scientists continue to debate these questions today. — **KATIE NEUBAUER**

EXOPLANET HELL

The Spitzer Space Telescope has found exoplanet HD 149026b glows at 3,700° Fahrenheit — the hottest planet yet discovered.

HIDING IN PLAIN SIGHT

Three dwarf galaxies, forged when NGC 5291 collided with another galaxy, contain 2 times more dark matter than visible matter.

ROGUE BLACK HOLES

Black holes ejected from galaxy centers likely retain their accretion disks, and thus could remain visible for millions of years.

MATTER WINS BATTLE

Calculations show matter will forever dominate radiation, even as dark energy pushes the universe apart.

COROT'S FIRST PLANET

French astronomers have discovered a "hot Jupiter" orbiting a Sun-like star. It's the first planet detected by the COROT satellite.

JET-SETTING DWARF

Gaseous jets spew from the 24-Jupiter-mass brown dwarf 2MASS1207–3932. This is the smallest object known to harbor jets.

COSMOLOGY'S END

Physicists say the universe will appear static in 3 trillion years, when everything outside the Local Group will lie beyond our visible horizon.

BLOWING UP BIG TIME

Supernova 2006gy is the brightest ever seen — 100 times brighter than normal. It marked the death of a 150-solar-mass star.

MEET THE NANO-NAUTS

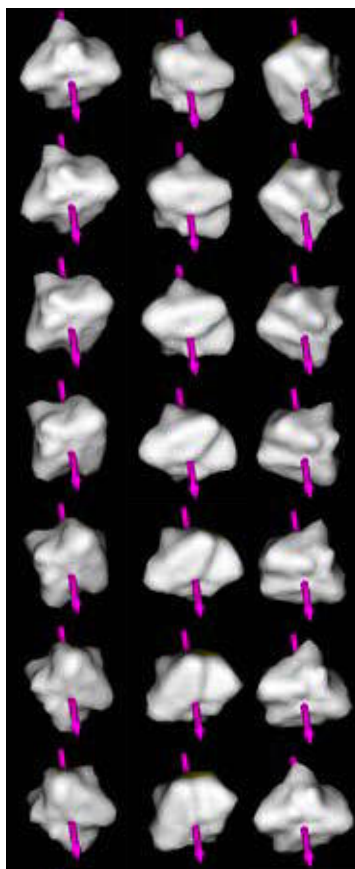
Scottish engineers are designing shape-shifting planet probes tiny enough to be carried on the wind.

RED PLANET ERUPTION

The Spirit rover has found the 6-foot-high (2 meters) plateau "Home Plate" consists of basalt formed from explosive volcanic activity.

Storm surge

Cassini observations show giant storms likely power Saturn's winds. Planetary scientists previously thought the jet-stream winds energized the rotating storms.



Light alters asteroid spins

Two research teams report light can modify asteroids' spins and orbits. Although theory says this should be the case, astronomers lacked concrete observations. Now, that evidence is in.

Light influences asteroid fates by a mechanism known as YORP: the Yarkovsky-O'Keefe-Radzievskii-Paddack effect. After sunlight warms an asteroid, its surface emits infrared photons that introduce a turning force, or torque, speeding up or retarding the asteroid's spin.

Astronomers led by Stephen Lowry of Queens University Belfast observed YORP's influence on the asteroid 2000 PH₅ as it passed through Earth's neighborhood. The team reported online in *Science* March 8 that YORP boosts the asteroid's spin about 1 millisecond per year. It currently completes one rotation in just over 12 minutes. In 15 to 40 million years, 2000 PH₅'s spin could increase enough to cause it to fly apart.

In a study published online in *Nature* March 7, Mikko Kaasalainen of the University of Helsinki and colleagues focused on near-Earth asteroid 1862 Apollo. By fitting patterns of sunlight reflected off the asteroid to a computer model, the astronomers determined YORP has caused Apollo to gain a full extra rotation per orbit during the past 40 years. — **D. P.**

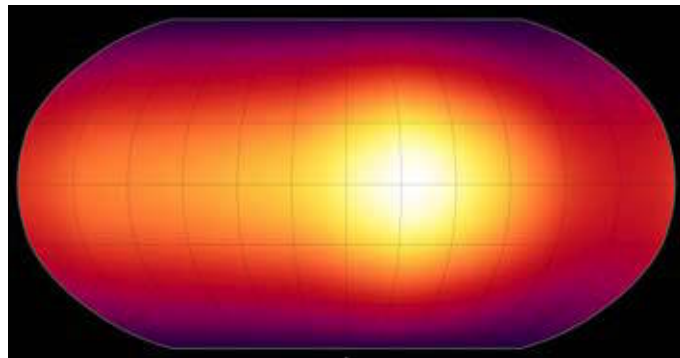
◀ **SPIN CYCLE.** This series of 3-D radar renderings (view top to bottom, then left to right) shows one rotation of asteroid 2000 PH₅. The purple arrows represent the asteroid's spin axis. ESO

How's the weather?

Astronomers have now mapped cloud-top features in an exoplanet's atmosphere. The map shows a bright hot spot located some 30° away from "high noon," which suggests fierce winds should dominate this world's weather.

Researchers used the Spitzer Space Telescope to measure the heat radiated by the planet as it circles the Sun-like star HD 189733, which lies 60 light-years from Earth in the constellation Vulpecula. The planet races around its star every 2.2 days at a distance of just 3 million miles (5 million kilometers).

The planet, with a mass and diameter slightly larger than Jupiter's, gets blasted with nearly 1,000 times the radiation per square inch that the Sun delivers



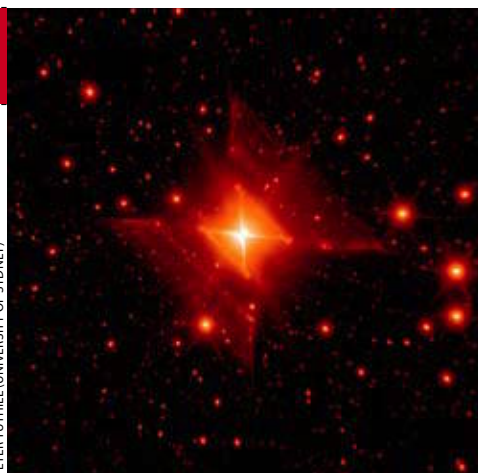
HOT SPOT. This full-globe map of the exoplanet HD 189733b reveals a hot spot about 30° away from high noon.

to Earth. The energy raises the exoplanet's daytime temperature to as much as 1,700° Fahrenheit (925° Celsius).

This occurs in a hot spot about twice as big as Jupiter's Great Red Spot offset some 30° of longitude from high noon. (The exoplanet should be tidally locked, with one hemisphere permanently facing its parent star.)

This offset implies winds blow as fast as 6,000 mph (10,000 km/h). The powerful winds also keep nighttime temperatures a surprisingly balmy 1,200° F (650° C).

The research team, led by Heather Knutson of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, reported its observations in the May 10 issue of *Nature*. — **R. T.**



STAIR STEPS. The Red Square nebula's symmetry shows for the first time in this high-resolution, adaptive-optics image.

Red Square at night

A red sky at night may be a sailor's delight, but astronomers couldn't be happier with the discovery of a reddish nebula having perfect symmetry. Dubbed the Red Square by codiscoverer Peter Tuthill of the University of Sydney in Australia, the nebula will make a grand celestial laboratory for studying how nature creates such complex systems.

"The Red Square nebula is the most symmetrical object of comparable complexity ever imaged," says Tuthill. He and James Lloyd of Cornell University in Ithaca, New York, found the nebula surrounding the hot blue star MWC 922.

The researchers imaged the nebula with the adaptive-optics system on the 200-inch Hale Telescope at Palomar Observatory. This near-infrared image reveals twin conical cavities on opposite sides, each adorned with a series of sharply defined linear rungs along the axis. Equally intriguing are a series of faint radial spokes, like the teeth of a comb, beyond the outer rung.

Tuthill and Lloyd liken the nebula's structure to the symmetric gas rings around Supernova 1987A. "We're not saying that MWC 922 is about to explode as a supernova, but we're not ruling it out either," adds Tuthill. The researchers announced their discovery in the April 13 *Science*. — R. T.

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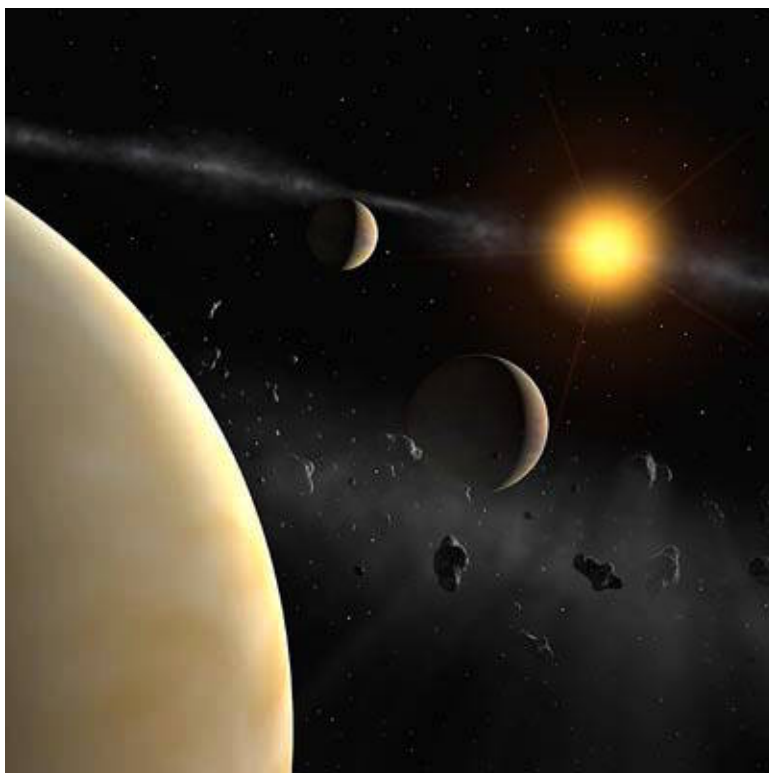
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Hot oceans ahoy!

Astronomers now have the capability to discover “hot ocean planets” around other stars, according to a report to be published in *Icarus*. Computer simulations show such a watery world would consist of a rocky core surrounded by a thick mantle of ice topped with a 60-mile-deep (100 kilometers) skin of liquid water.

In the report, a team led by Franck Selsis of the Centre de Recherche Astrophysique de Lyon in France argues that astronomers could spy hot ocean planets, which orbit close to their host stars. The technique involves combining data from the COROT space telescope and the High Accuracy Radial velocity Planet Searcher (HARPS), a spectrograph attached to the 3.6-meter telescope at the European Southern Observatory in La Silla, Chile.

Close-orbiting ocean planets might be too toasty to host earthlike life-forms. But NASA's upcoming Kepler mission, slated for launch in 2008, could detect ocean worlds farther from their suns, which would be cooler and possibly friendlier to life.

“Kepler could detect ocean planets in the habitable zones of their stars,” Selsis says. But, he cautions, we don't know yet if water-rich or rocky planets are more hospitable to life. — **D. P.**

HARPS MUSIC. The same instrument that revealed the existence of gaseous “hot Neptunes” around the Sun-like star HD 69830 (depicted in this illustration) could detect the first hot ocean exoplanets. ESO

How to weigh a black hole

Astronomers have just added a new tool to their kits: a way to estimate a black hole's mass based solely on X-ray observations.

Nikolai Shaposhnikov and Lev Titarchuk, astrophysicists at NASA's Goddard Space Flight Center in Greenbelt, Maryland, successfully tested their technique on the black hole lurking in the Cygnus X-1 binary system. Its weight: 8.7 times the Sun's mass, plus or minus 0.8 solar-mass. Shaposhnikov and Titarchuk detailed their findings in the July 1 issue of *The Astrophysical Journal*.

Astronomers had previously “weighed” this black hole by measuring the slight wobble its gravity induces in its companion star's orbit. That estimate put the black



NASA/HONEYWELL MAX-Q DIGITAL GROUP/DANA BERRY

TRAFFIC JAM. This artist's impression depicts a binary system similar to Cygnus X-1. An accretion disk, emitting X-ray jets, forms around a black hole (left) drawing gas from its blue-supergiant companion.

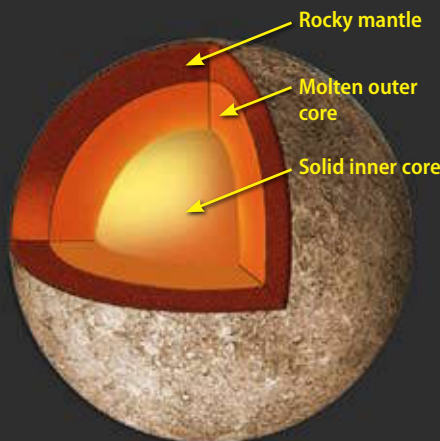
hole's bulk at about 10 solar-masses. Titarchuk notes the new method “can determine a black hole's mass when alternative techniques fail.”

In Cygnus X-1, the black hole draws gas from its blue-supergiant companion. The gas spirals around

to form a whirlpool-like accretion disk. As material is sucked inward, a celestial traffic jam develops at the accretion disk's edge. The more massive the black hole, the farther out the “traffic” piles up.

Shaposhnikov and Titarchuk showed a predictable relationship

exists between the size of the traffic jams and the flickering X-ray signals the accretion disks emit called quasi-periodic oscillations (QPOs). So, measuring the QPO flicker rate tells you, indirectly, the mass of the black hole causing the jam. — **D. P.**



SQUEEZABLY SOFT. Mercury probably has a partially molten core that spins independently of its rocky outer mantle.

Mercury's mushy middle

Mercury probably has a partially molten interior, which could explain why the planet has a weak magnetic field. A team led by planetary scientist Jean-Luc Margot of Cornell University in Ithaca, New York, revealed Mercury's apparently mushy middle by measuring slight blips in how fast the planet spins on its axis. The team reported its findings in the May 4 *Science*.

Astronomers once assumed the tiny planet — with a mass only 5 percent of Earth's — cooled and solidified long ago. But on its 1974–75 mission, Mariner 10 discovered Mercury's weak magnetic field. This suggested Mercury, like Earth, contains a solid inner core surrounded by a molten, iron-rich outer core. On Earth, convection currents in the molten layer spawn the planet's magnetic field.

To explore Mercury's interior, Margot and his colleagues bounced radar beams off the planet's surface at intervals over a 5-year period. The scientists then clocked the reflections with widely spaced pairs of radio telescopes on Earth. Gradually, the team collected enough measurements to pin down slight variations in Mercury's spin rate.

The spin variations, or librations, arise as the Sun tugs on Mercury. The librations were double what they would have been for a planet solid all the way through, strongly suggesting a partially molten core. — **D. P.**

Old star Astronomers have radioactively dated a star in our galaxy at 13.2 billion years old, meaning it was born just 500 million years after the Big Bang.



T. A. RECTOR AND B. A. WOLFF/NOAO/AURA/NSF

PARTY CRASHER. Within the next 5 billion years, the Andromeda Galaxy (seen here) will collide and merge with the Milky Way, exiling our solar system into the galactic boondocks.

The solar system's fate

Prepare for exile: As the Andromeda Galaxy (M31) collides with the Milky Way during the next 5 billion years, the solar system will be cast into the merged galaxy's outer rim.

So say T. J. Cox and Avi Loeb of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, who performed the new calculations. "You could say that we're being sent to a retirement home in the country," says Cox, who likens our current residence to the Milky Way's suburbs.

The new computer simulations show changes start in just 2 billion years, when the galaxies make their first close pass.

Any future solar system resident would see the night sky evolve from a strip of stars (the Milky Way seen edge-on) to a muddled mess.

The two galaxies will swing around each other a couple of times before merging into a single giant elliptical galaxy about 5 billion years from now. At that stage, the Sun will be approaching its red-giant phase and reside 100,000 light-years from the new galaxy's center. (That's about 4 times farther than we are now from the Milky Way's core.) The astronomers have submitted their research to the *Monthly Notices of the Royal Astronomical Society*. — **R. T.**

What lurks between

ga

An ever-expanding portion of the cosmos contains virtually nothing, but what little there is may tell astronomers how galaxies formed and evolved. /// **BY BRUCE DORMINEY**

Headlights plying through fog on a back-country road hardly evokes visions of the distant cosmos. But while the best halogens light the driver's way, they also serve as "fog probes" to a distant onlooker. Quasars, the halogen headlights of the far universe, illuminate the near-nothingness of the intergalactic medium (IGM).

This hard-to-detect, poorly understood IGM may account for a majority of the universe's baryonic matter — the ordinary stuff made of protons and neutrons we're all familiar with. Yet, more than half of the IGM has yet to be accounted for.

Where is this missing matter? Astronomers think it's hiding in a warm-to-hot intergalactic medium in the local universe, and in the form of atomic hydrogen, helium, carbon, oxygen, silicon, and a handful of other elements out to the edge of the observable universe. Researchers now are turning their efforts to detecting this elusive material.

Next to nothing

Imagine having a box with a volume of 1 cubic meter (35 cubic feet) that you could put anywhere in the universe. Place it just beyond the Sun's influ-

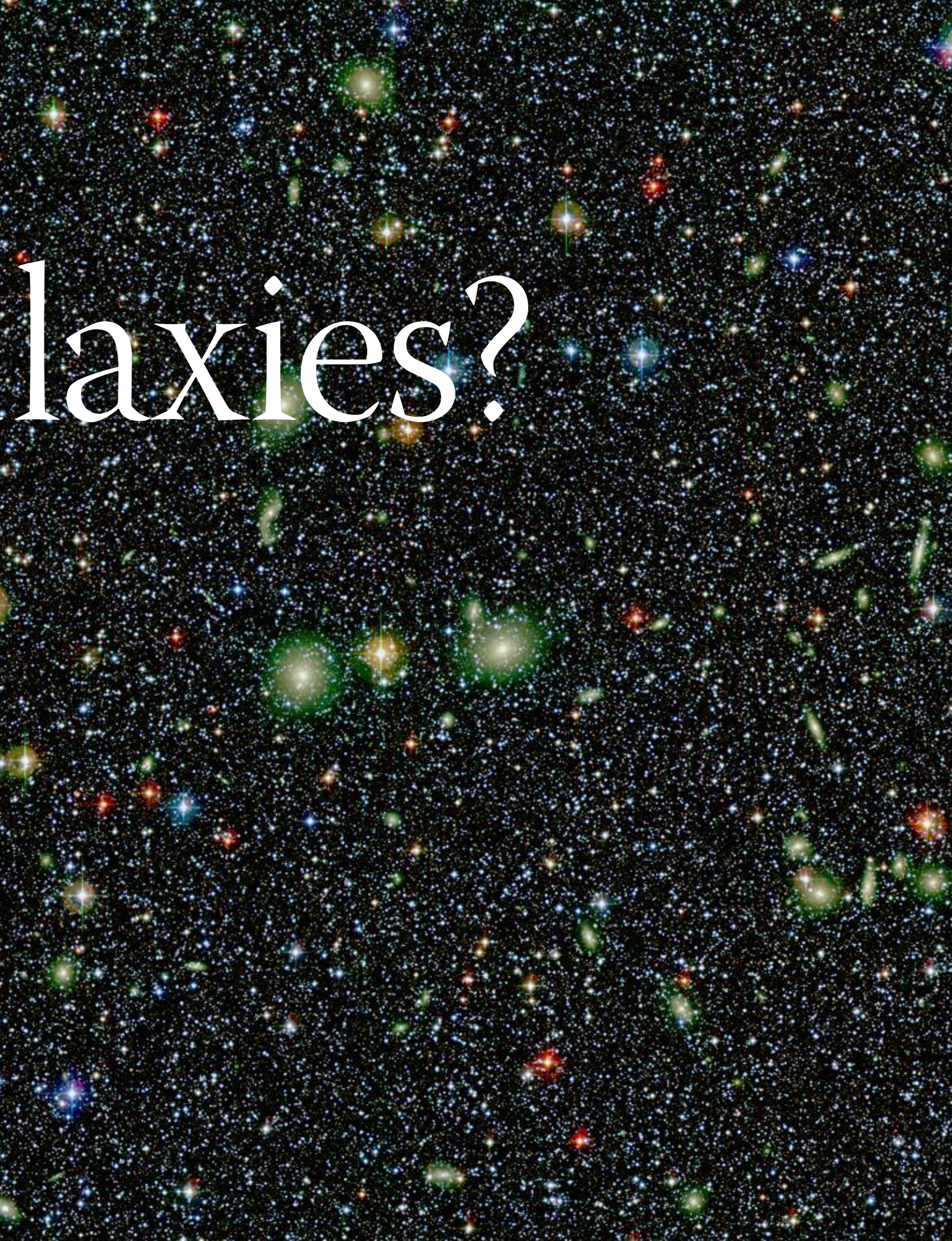
ence in the local interstellar medium, and an average of 100,000 atoms would fill the box. Although that may sound like a lot, the same volume of Earth's sea-level atmosphere would contain about 100 billion billion times more atoms.

But compare that with the sparse nature of the intracluster medium (ICM), which surrounds galaxies in gravitationally bound clusters. In the ICM, a cubic-meter box would contain some 100 atoms, an average density comparable to two sugar cubes spread evenly throughout a sphere Jupiter's size. Still, this is a veritable atomic metropolis compared with the intergalactic medium, which encompasses the voids between galaxy clusters. In the IGM, on average, you'll find only 1 atom per cubic meter.

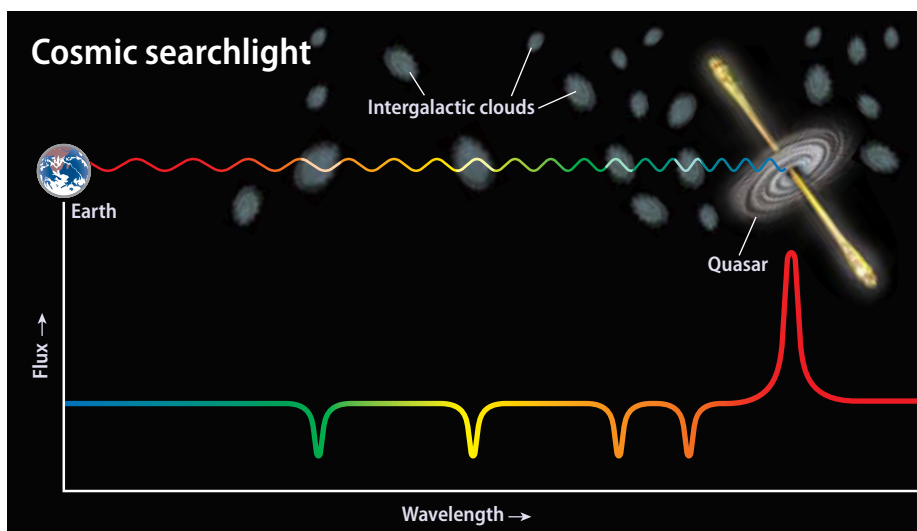
Computer models of the universe's large-scale structure show massive superclusters and vast voids appear relatively uniform. In reality, there are exceptions: We know at least two great "walls" of

GALAXIES FILL THE UNIVERSE, don't they?

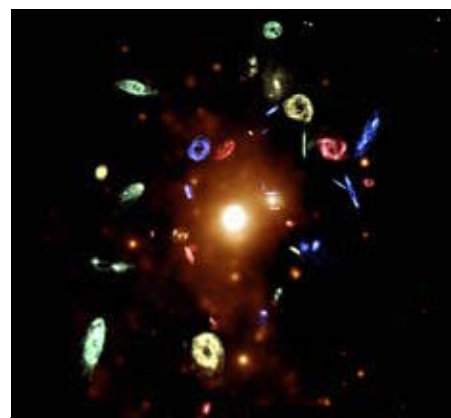
While massive clusters like ACO 3627 in Norma garner most of the attention, the voids between clusters make up a bigger volume. Astronomers are zeroing in on these next-to-nothing voids. ESO



Galaxies?

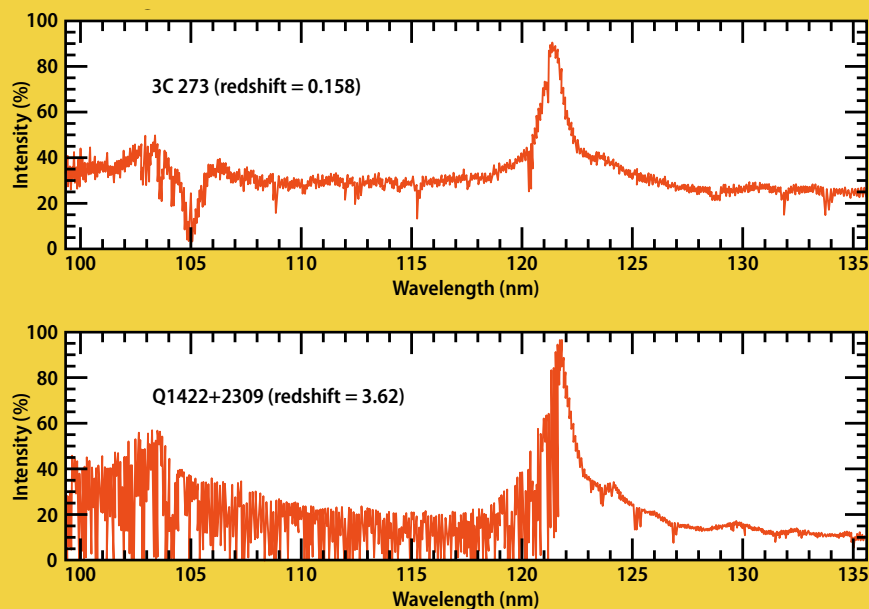


DISTANT QUASARS LIGHT UP low-density clouds in the intergalactic medium. Because each intervening cloud has a smaller redshift than the quasar, it absorbs radiation to the blue side of the quasar's Lyman-alpha emission. *ASTRONOMY: THEO COBB*



GALAXIES LOSE MASS in the Virgo cluster as hot gas strips them. In this image, the hot intracluster gas appears as a diffuse X-ray glow, while radio data show neutral hydrogen in 47 spiral galaxies. These galaxies are shown 10 times their actual sizes. *NRAO/AUI/AEREE CHUNG ET AL. (COLUMBIA UNIVERSITY)*

Creating a forest's trees



THE LYMAN-ALPHA "FOREST" consists of narrow absorption lines in a quasar's spectrum. Relatively nearby quasars like 3C 273 show a smattering of such lines, while distant ones like Q1422+2309 show a thicket. To make comparison easier, these spectra have been shifted to a common scale. *WILLIAM KEEL (UNIVERSITY OF ALABAMA)*

galaxies stretch for hundreds of millions of light-years in the cosmos.

On smaller scales, however, similar cosmological models appear much more inhomogeneous. On this more local scale, filaments snake their way along clusters and superclusters of galaxies. Astronomers think these filaments are rife with dark matter — the still-mysterious stuff that emits little or no light, yet comprises 80 to 90 percent of material in the universe.

"Voids fill a much larger fraction of the universe than clusters because, as the universe expands, the clusters contract while the voids grow," says astrophysicist Michael Vogeley of Drexel University in Philadelphia. "The cluster regions act like higher-density universes that recollapse on themselves, while the voids act like underdense universes that expand quickly and fill as much space as possible, until they bump into the clusters and each other. Depending on how

you define voids, they conservatively make up 50 percent of the universe."

Galaxies arrange themselves along the weblike filamentary structure surrounding such voids, forming clusters and superclusters of galaxies in dense knots where the filaments intersect. An exceedingly low-density gas fills the vast spaces between the clusters and superclusters.

Seeing the forest's trees

To get at the makeup of the IGM, astronomers use distant quasars as luminous probes. These brilliant beacons — the centers of galaxies where supermassive black holes accrete matter — illuminate the material that lies along our line of sight like auto headlights reveal fog on a humid night.

The IGM's secrets lie in the so-called Lyman-alpha forest — a series of narrow absorption lines (mostly of atomic hydrogen) seen in most quasar spectra. A quasar's strongest emission comes in the Lyman-alpha line of hydrogen, at a rest wavelength of 122 nanometers. Of course, the expansion of the universe shifts this emission to longer (redder) wavelengths. As the radiation passes through intervening clouds of hydrogen gas, each cloud removes energy at the wavelength of Lyman-alpha. But, because each cloud lies closer to Earth than the quasar, the absorption line is not

Bruce Dorminey is the author of *Distant Wanderers: The Search for Planets beyond the Solar System*. A frequent contributor to *Astronomy*, he also edits the astronomy-related web site cosmiccontroversy.com.



A GALACTIC SUPERWIND blows from M82 in Ursa Major. Such winds, fueled by supernovae and intense star formation within the galaxy, eject copious amounts of gas into the intergalactic medium. NASA/ESA/THE HUBBLE HERITAGE TEAM (STScI)

shifted as far to the red, so the spectrum contains a “forest” of lines to the blue side of the quasar’s Lyman-alpha emission.

Cosmologists seeking to piece together the evolutionary history of large-scale structure and galaxy formation routinely probe the IGM for metals. (Astronomers refer to any element with an atomic weight heavier than helium as a “metal.”)

It’s been more than a decade since researchers first detected metals in the Lyman-alpha forest using the High Resolution Echelle Spectrometer on the Keck I Telescope. So far, they have identified the absorption signatures of atomic oxygen, carbon, silicon, magnesium, and iron.

Where did the metals come from? Within a few minutes after the Big Bang, the universe created all of the hydrogen and much of the helium it has ever known. But heavier elements didn’t arise until stars did. The nuclear fires in the cores of massive stars cook up metals, and supernovae ultimately deliver them into the interstellar medium.

If not for dense star-forming regions and the supernovae they spawn, the IGM would have almost no chemical enrichment. So, how do star-forming regions eject material into the surrounding cosmos? They apparently have done so uniformly and throughout most of cosmic history.

This question remains a cosmological point of contention. Theorists have come up with several ways to enrich the IGM. Perhaps it came about when the universe’s earliest massive stars, known as Population III, exploded. Or maybe the supermassive black holes powering distant quasars ejected material through their powerful jets. Other ideas for getting material into the IGM include galactic “superwinds” generated by heat within galaxies themselves, and material stripped from and outgassed by galaxies interacting in clusters.

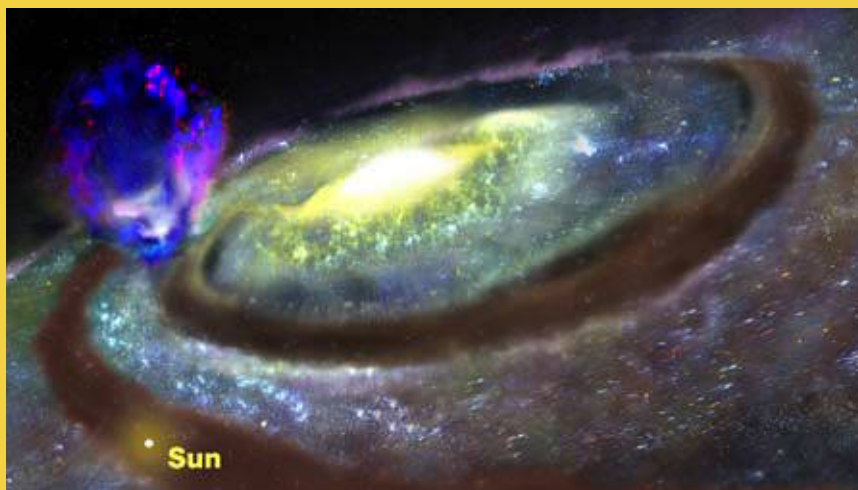
“The amount of carbon and oxygen in some of the absorption systems is higher than one might have theoretically expected,” says Todd Tripp of the University of Massachusetts in Amherst. Tripp has

used the Hubble Space Telescope to investigate the IGM along sight-lines that avoid galaxy clusters. “So,” he says, “an important new question is: How did these absorbers become so highly enriched?”

To answer this question, cosmologists need to understand the universe’s history of element creation. Unfortunately, they are missing the first few chapters of this cosmic “book” and, thus, have to infer the universe’s earliest astrochemistry. Observational astronomers using the current generation of 8- and 10-meter ground-based telescopes are probing back to a time just 1 billion years after the Big Bang. Cosmologists view this as the era of the first galaxies, perhaps only a few hundred million years after the first stars formed.

Early enrichment

Even at this early epoch, the IGM appears enriched at a fairly uniform level. Perhaps these metals indicate so-called pre-galactic enrichment, where the earliest Population III stars went supernova and threw their



A superbubble in the Milky Way Galaxy contains a million solar-masses of material. The bubble, discovered through radio observations, lies about 23,000 light-years from Earth and spans 10,000 light-years. BILL SAXTON (NRAO/AUI/NSF)

BLOWING BUBBLES IN THE MILKY WAY GALAXY

Astronomers at the National Radio Astronomy Observatory's Green Bank Telescope have detected a nearby microcosm of what may be contributing to the enrichment of the distant intergalactic medium (IGM). The team found a galactic "superbubble" rising 10,000 light-years above the Milky Way Galaxy's plane 23,000 light-years from Earth. It lies in the direction of Scutum, some 30° from the galaxy's center. The bubble contains about a million times the Sun's mass and is driven by an energy equivalent to some 100 supernovae.

NRAO astronomer Jay Lockman was studying the Milky Way's hydrogen structure when he noticed that, in this sector of sky, the gas seemed to rise farther and farther out of the galaxy's plane. One of his doctoral students, Yurii Pidopryhora, took on the observations as part of his doctoral thesis. "If a superbubble has enough energy to break out of the galaxy's disk, then it becomes a superwind," says Lockman. "Much earlier, during the era of peak star formation, it's plausible that superbubble events were much more energetic than the one we found, and could therefore blow more metals into the IGM."

The best nearby example of a superwind lies some 12 million light-years away in M82, a starburst galaxy in Ursa Major. About a quarter of the Milky Way's size, M82 outgasses along lobes that run perpendicular to the galaxy's plane. Although superwinds likely can escape the gravity of smaller galaxies, such as M82, and vent gas into the IGM, the jury is still out on how easily superwinds form and vent from massive galaxies. — *B. D.*

metal by-products into the fledgling universe. Or maybe theorists need to fine-tune their cosmologies to account for earlier galactic evolution, and, therefore, earlier galactic enrichment of the IGM.

"The metals that have been seen in the diffuse Lyman-alpha forest are not in the voids," says Chuck Steidel, an observational astronomer at Caltech who is trying to learn how much mass high-redshift galaxies have lost to the IGM. "They are in lower-density regions than you might find galaxies, but we don't really know where they are with respect to galaxies. Even when you go to the weakest carbon systems that you can detect right now, it still looks like they are quite strongly correlated to galaxies."

Most cosmologists think metal enrichments they see at these early times are the product of both pre-galactic enrichment from the earliest stars and supersonic winds from the earliest galaxies. Superwinds from newborn galaxies likely appeared as early as 800 million years after the Big Bang. These high-redshift outflows blow out 100 times more mass than their counterparts in the local universe.

Triggered when supernova remnants in starburst galaxies overlap, these hot superbubbles build up high pressures and then burst into the intracluster medium. Intracluster gas temperatures typically range from 100,000 to 10 million Kelvin. By contrast, the Sun's surface glows at 5,800 Kelvin.

Researchers got their first inkling this hot intracluster gas exists in the mid-to-late 1960s, when sounding rockets and balloons lofted the first X-ray detectors above Earth's atmosphere. Today, astronomers routinely capture faint X rays from this elusive Warm-Hot Intergalactic Medium (WHIM) with the latest generation of space-based X-ray telescopes, such as NASA's Chandra X-ray Observatory and the European Space Agency's XMM-Newton.

"We discovered two Warm-Hot IGM filaments," says Fabrizio Nicastro, an astrophysicist at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, who, with colleagues, has studied the local ICM in both ultraviolet and X-ray wavelengths. "We estimate that if the baryons within these two filaments are representative of the WHIM distribution in the universe . . . we have 'corrected' the missing baryon problem within a few-percent uncertainty." Nicastro's confidence would soar if they could observe 100 more such filaments with similar results.

Stars in the mix

Although such gas and filaments may represent up to 40 percent of the baryonic matter in the local universe, arguably the most unexpected form of intracluster matter discovered so far is ordinary stars. In nearby galaxy clusters like Fornax, Coma, and Virgo (the nearest large cluster to Earth), astronomers have found evidence of significant numbers of intracluster stars.

Fritz Zwicky, who discovered dark matter in galaxy clusters, also was the first astronomer to point out excess luminosity in the Coma cluster. In a 1951 paper based on his observations, he noted the discovery of "an extended mass of luminous intergalactic matter of very low surface brightness." Zwicky also mentions "luminous intergalactic matter" concentrated around the cluster's center. It took another 4 decades to confirm Zwicky's suspicions about intracluster stars.

By 1990, astronomers had detected planetary nebulae in the Virgo cluster. These bright, glowing gas clouds represent the end stage of a normal star's life, after it has puffed off its outer atmosphere. More recently, astronomers have observed intracluster red-giant stars — evolved stars that have exhausted their core hydrogen and have swelled to enormous size. Most likely, none of these stars formed in situ.



ROGUE STARS — and possibly planets — lurk among the galaxies of the Virgo cluster. Hubble observations reveal up to a trillion such stars, like the red giant seen looming on this hypothetical planet's horizon, stripped or ejected from member galaxies. JAMES GITLIN (STSC)

“These planetary nebulae are the tip of the iceberg,” says George Jacoby, astronomer and director of the WIYN Telescope at the National Optical Astronomy Observatory in Tucson. “Because their light is compacted into very narrow wavelengths, you can use filters to isolate those bands and block out the sky and galaxy backgrounds, making them easier to see. We find between 10 and 20 percent of light coming from a galaxy cluster comes from intracluster stars.”

Astronomers estimate that for every intracluster planetary nebula, there should be roughly 10 million main sequence stars, whose cores stably burn hydrogen into helium. These stars simply glow too faintly to be detected individually, but their presence has been inferred by ultra-deep-field photometry. How they arrived in intracluster space remains an open question.

Astronomers suspect stars stripped from dwarf galaxies or the fringes of more massive galaxies through the gravitational “harassment” of other galaxies make up the majority of intracluster stars. Still, a few percent of Virgo’s intracluster stars

likely were ejected at hypervelocities from massive elliptical galaxies when the stars gravitationally interacted with 100-million-solar-mass binary black holes.

Planets, anyone?

Could any of these intracluster stars harbor planets? The numerous stripped stars don’t seem to be prime candidates, simply because they should have low metal content. But those ejected by supermassive binary black holes likely started as more mature, metal-rich stars, which could have planets. Now the question becomes: Could any such planets have survived? Under such extreme conditions, almost anything could happen. A planet might be ejected without its star, or vice versa. Or perhaps both would survive, but with the planet’s orbit disrupted.

Pennsylvania State University astronomer Steinn Sigurdsson says a star must “thread the needle” to be ejected into the ICM by a supermassive binary black hole. That means the star has to squeeze between the two orbiting supermassive black holes, while getting close enough to one of them

to pick up the speed necessary to escape from its parent galaxy.

“Stars would need to pass some 1,000 astronomical units [Earth-Sun distances] from one of the black holes to pick up enough of a ‘sling shot’ to leave the galaxy,” says Sigurdsson. “Inner planets would survive most such encounters, while the outer planets would be stripped off or strongly scrambled in their orbits in a significant fraction of encounters.”

Of the billions of stars ejected by supermassive binary black holes, Sigurdsson says at least some of them would have planets in habitable zones. And a fraction of those planets would survive the ejection and maintain stable orbits around their stars. Still, these systems would have to contend with the cluster’s X-ray environment.

“The X-ray density is low in the intracluster medium, so the X-ray flux would be relatively low,” says Sigurdsson. “There would be a stellar wind screening the worst of it, just as with the Sun, which happens to be in a relatively hot bubble in the interstellar medium. The planets should be just fine.” ■



AT LAS CAMPANAS, a peak in the Andes Mountains of Chile, astronomers will study hundreds of supernovae in distant galaxies to help them understand dark energy, the mysterious force that fuels the accelerating pace of cosmic expansion. One workhorse of the supernova survey, the Swope Telescope (above), peers from under its dome (near right) at Las Campanas. The larger dome at far right houses the Du Pont Telescope, also assisting in the supernova project. ASTRONOMY: ROEN KELLY; TELESCOPES: CARNEGIE OBSERVATORIES; GALAXY: ADAM BLOCK/NOAO/AURA/NSF

Will supernovae shine new light on DARK ENERGY?

Bob Berman goes behind the scenes at Carnegie Observatories to get the scoop on an unprecedented survey of exploding stars.

The Andes Mountains rose like shark teeth from Chile's vast Atacama Desert into the black, starry sky. As I drove slowly along a tortuous mountain road with my headlights off, it felt like the Moon, as if there were no air at all between myself and the heavens. There wasn't even a guard rail along the road to reassure me I wouldn't tumble off the slope of Cerro Las Campanas — the mountain, 7,540 feet (2,300 meters) above sea level, where the Carnegie Institution of Washington built its premier observatory. Here, astronomers peer into distant corners of the universe. Ahead, illuminated eerily by the glow of the Milky Way, stood some of the world's greatest telescopes. Tonight, I would visit astronomers conducting research with the workhorse instruments of Las Campanas Observatory: the 1-meter (40 inches) Henrietta Swope Tele-

scope, the 2.5-meter (100 inches) Irénée du Pont Telescope, and the twin 6.5-meter (21 feet) Magellan telescopes.

I was relieved to park safely alongside one of the Magellans, where photons of light from faint galaxies had been accumulating since dusk. With 9 hours more to go, the astronomers inside had nothing to do but wait and talk.

"Magellan costs \$40,000 a night to operate," Carnegie astronomer Barry Madore told me. "But we can still be playful and innovative and take some risks." Madore was alluding to Carnegie's tradition of keeping its astronomers on an unusually long leash, freer to explore new ideas. He looked around the darkened room and recited the institution's mantra: "Carnegie is an inspired way of doing science."

I chatted with astronomer Dan Kelson as he analyzed the data-packed light fingerprints, or spectra, of galaxies billions



THE HUNTINGTON LIBRARY

INDUSTRIALIST Andrew Carnegie (left, walking with astronomer George Ellery Hale) financed construction of Hale's Mt. Wilson Solar Observatory.



THE HUNTINGTON LIBRARY

EDWIN HUBBLE, shown at the controls of Mt. Wilson's 100-inch Hooker Telescope, discovered the universe's expansion while a Carnegie Observatories astronomer.



CARNEGIE OBSERVATORIES

WENDY FREEDMAN, current director of the Carnegie Observatories, heads a new study of supernovae at Carnegie's Las Campanas Observatory in Chile.

of light-years beyond our own Milky Way. Kelson's enthusiasm for observing is still very much intact, despite the exclusive reliance on spectrographs and other electronic instruments at Las Campanas.

"I was an amateur astronomer, and, when I became a professional, I had to fall in love with it all over again," Kelson said. "Spectra take on a beauty all their own. Trust me, professionals are gaping, too."

He gestured to the spectrometer connected to one of the Magellan scopes, the largest light-gathering bucket on the mountain. "This instrument is measuring 4,000 galaxies at once," Kelson says. "It's an all-you-can-eat type of data collection."

The astronomers at Las Campanas are indeed hungry — for clues to understanding dark energy, the mysterious agent some cosmologists believe powers the universe's accelerating expansion. Carnegie astronomers enjoy some of the clearest skies on the planet. This lets them feast nightly on light from distant galaxies that host the telltale glare of type Ia supernovae, a special type of exploding star that could help solve the riddle of dark energy.

Nothing less than the fate of the universe is at stake.

Bob Berman is an Astronomy contributing editor. His column, "Bob Berman's strange universe," appears monthly in the magazine.

Candle power

Astronomers use type Ia supernovae to measure vast intergalactic distances. If you know the intrinsic brightness of a light source, you can determine how far away it lies. For instance, a candle flame seems glaringly bright if you stand nose to nose with it. The light streaming from the wick is its intrinsic brightness. But seen from a distance, the candle seems dimmer. This is its apparent brightness — the brightness of the candle from the observer's point of view. The difference between the intrinsic and apparent brightnesses reflects the distance between you and the candle's flame.

Astronomers use type Ia supernovae as "standard candles" for measuring vast distances. At peak brightness, they are visible for billions of light-years. But, more important, every type Ia supernova cranks out roughly the same amount of light. By measuring each blast's peak brightness, astronomers can figure out its distance from Earth.

The ability to measure distances accurately is essential to cosmology. As light from a supernova in a faraway galaxy travels to Earth, the expanding fabric of space-time stretches it. This measurably shifts the light toward the red end of the spectrum. Measuring the redshifts of type Ia supernovae at a variety of distances provides a record of the universe's rate of expansion in the past — and clues to its future.

In 1998, observations of type Ia supernovae in distant galaxies revealed something strange and utterly unexpected to cosmologists: The universe is expanding faster now than it was in the past. Yet, if you had cracked any astronomy textbook in the mid-1990s, you would have read that the expansion has gradually slowed down since shortly after the Big Bang.

Instead, something is boosting the expansion. Cosmologists think it might be dark energy, a kind of antigravity force acting uniformly throughout the universe. In the early cosmos, gravity's attraction dominated. But as things spread out more and more, dark energy began to exert its muscle. The expansion began to speed up.

The fate of the universe is a pretty big deal, and a lot of what we think we know about dark energy rests on the observations of type Ia supernovae. But are these exploding stars really the accurate standard candles we think they are? Or are we missing something important?

For instance, were type Ia supernovae dimmer in the early universe? If so, this would give us inaccurate distance measurements. And to what degree does interstellar dust dim supernova blasts seen from Earth? This could also distort distance measurements. Finally, do all type Ia supernovae truly beam out the same amount of light when they explode or does the brightness

A CENTURY OF DISCOVERY AT CARNEGIE OBSERVATORIES

1902
Andrew Carnegie spends \$2 million to found the Carnegie Institution of Washington.

1904
The Carnegie Institution grants \$300,000 to establish Mt. Wilson Solar Observatory.

1908
George Ellery Hale discovers Sun's magnetic field using Mt. Wilson's 60-foot solar telescope; 60-inch telescope on Mt. Wilson sees first light.



MIGUEL ROTH, director of Las Campanas Observatory, oversees the daily operation of the site's telescopes, living quarters, and other facilities. ANJALI BERMAIN

vary depending on the star's evolutionary stage when it explodes? Any of these factors could throw the whole distance-measuring business out the window.

The issue was, and remains, critical to cosmology. It's been called the most important unresolved issue in astronomy. To do its bit for the cause, Carnegie is bringing to bear some of Earth's finest telescopes, clearest skies, and most-advanced instruments to make sure type Ia supernovae are telling us what we think they are.

Man of steel and stars

The supernova sleuths at Las Campanas Observatory can thank one man for their exceptional view of the universe: Andrew Carnegie, a short, eccentric Scotsman who, in the 19th century, became the richest industrialist in the world and commenced to build the world's greatest telescopes.

Carnegie Steel, later called U.S. Steel, propelled its owner into a royal life in a Scottish castle. But, at the start of the 20th century, Carnegie did a 180° turn. Formerly cursed as a "robber baron," he became a spendthrift philanthropist who eventually gave away every penny he had.

In addition to financing many other worthy causes, he founded the Observatories of the Carnegie Institution of Washington — now known informally as the Carnegie Observatories. In 1904, Carnegie

hired George Ellery Hale to be the first director of his fledgling astronomical institute. Hale, in turn, brought in the sharpest minds of the time. They included Harlow Shapley, who proved Earth does not lie at the center of the galaxy, and Edwin Hubble, who discovered the universe's expansion.

Hale and Carnegie fervently believed great discoveries demanded the world's biggest telescopes. So they built the Mt. Wilson Solar Observatory at a dark and sleepy site outside Los Angeles and started stocking it with huge scopes. The observatory's first completed behemoth sported a 60-inch (1.5 meters) mirror and opened in 1908. The 100-inch Hooker colossus followed in 1917, with its 9,000-pound mirror fashioned from wine-bottle glass.

At Mt. Wilson, Hubble discovered that the Andromeda Galaxy is not merely a nearby nebula but a separate "island universe," or galaxy. Not long thereafter, Hubble discovered the universe's expansion. Instantly, the cosmos became vastly larger.

"It ranked with the Copernican revolution," says Wendy Freedman, Carnegie Observatories' current director. "There are only a few times in history when you change the very nature of the universe."

Hale still wasn't finished. He obtained funds from the Rockefeller Foundation to build the 200-inch telescope on Palomar Mountain, California. Dedicated as the Hale Telescope when it opened in 1949, it remained the largest optical telescope for more than 3 decades.

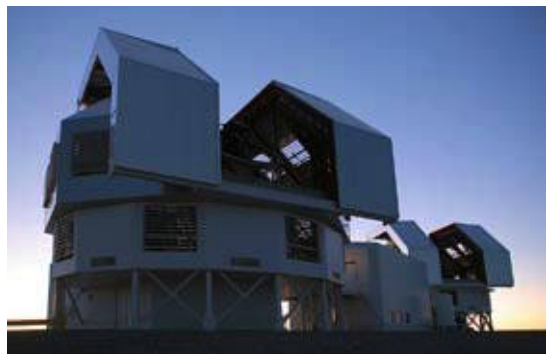
Southbound

In 1969, the Carnegie Observatories acquired a site on Las Campanas, where they built the 40-inch and 100-inch reflectors. In the 1980s, Las Campanas became Carnegie's principal observing site. The twin 21-foot Magellans began operating in 2000 and 2002, respectively.

As if this weren't enough, Carnegie and eight other scientific institutions are planning to build a new super-instrument, the Giant Magellan Telescope (GMT). The GMT will have a light-gathering capacity equivalent to a single 80-foot (24.5 meters) mirror. Carnegie and its partners hope to complete the telescope by 2016.



THE DU PONT TELESCOPE, with a light-gathering mirror 100 inches (2.5 meters) in diameter, started operating at Las Campanas Observatory in 1977.



THE TWIN MAGELLAN telescopes saw first light, respectively, in 2000 and 2002. They provide exceptional views of supernovae to Las Campanas' astronomers.



THE GIANT Magellan Telescope, shown in this artwork in the daytime, may join Las Campanas' other scopes in 2016. Its seven mirrors will equal the power of a single 80-foot-wide (24.5 meters) light-gathering surface. TELESCOPE IMAGES: CARNEGIE OBSERVATORIES

1917

The 100-inch Hooker Telescope sees first light.

1924

Edwin Hubble uses Hooker Telescope to determine the vast distance to M31 (Andromeda Galaxy), indicating that the Milky Way is but one of many galaxies.

1929

Edwin Hubble discovers expansion of the universe; proposes Hubble's law linking expansion velocity to galaxy distances.

1937

Olin Wilson discovers the first Wolf-Rayet star while working at Mt. Wilson Observatory.

How astronomers use supernovae to measure distances



At one unit of distance, the light covers a 1 by 1 area.

At two units of distance, the light spreads out over 4 times the area, so it is $\frac{1}{4}$ as bright at any given point.

At three units of distance, the light is $\frac{1}{9}$ as bright.

AS PHOTONS beam outward from a light source, they spread out over a greater and greater area. The total light the source produces (its intrinsic brightness) remains constant; but the amount of light an observer sees (the source's apparent brightness) decreases with distance at a predictable rate. As a result, the difference between intrinsic and apparent brightness reveals the observer's distance from the light source.

A white-dwarf star draws mass from a larger companion star. When the white dwarf's mass reaches a critical threshold (1.4 solar-masses), it explodes. Because type Ia supernovae explode at similar masses, their brightnesses are also similar.

White dwarf

Type Ia supernova

TYPE IA SUPERNOVAE provide an absolute reference, or "standard candle," for measuring distances. At peak brightness, these exploding stars produce roughly the same amount of radiation and, therefore, have very similar intrinsic brightnesses.

A venerable institute with a portfolio of major discoveries. A site boasting some of the planet's best seeing. And all this at a pivotal time in astro-history. No wonder Carnegie Observatories is devoting 300 nights per year to observations needed to solve the riddle of dark energy: Only a bona fide "greatest unsolved mystery" could be deemed a worthy target for its telescopes.

Troublemakers

I decided to go to Las Campanas Observatory to see what the Carnegie astronomers were up to. My seemingly endless journey began with a flight from New York to Miami, followed by another to Santiago, Chile. There, I met Las Campanas' Director Miguel Roth for dinner. We sat at an outdoor table in one of the many beautiful neighborhoods of that fascinating city.

Director for 17 years, Roth is gracious and handsome, exuding movie-star confidence. "We're known for our good food," he said when our entrées arrived. He wasn't talking about Chilean cuisine; he meant the

meals served to staff at Las Campanas. But Roth's pride in his workplace exceeds the merely gastronomical. "We're up at 2,300 meters, and it's really dark," he tells me. "The site is incomparable. We get 300 clear nights a year. The Atacama Desert stretches all around. The nearest corner store is 100 miles away."

Then Roth put down his fork and looked serious, explaining that it's not just the food that exceeds expectations at Las Campanas. "You won't find mediocre people at Carnegie," he said. "People here can be trouble, but they're worthwhile trouble."

The staff astronomers I spoke to echoed Roth's depiction of Carnegie Observatories as an exceptional environment for doing science. "We have more access to more telescope time than astronomers elsewhere," one boasted. Another emphasized that working in a private research institution means staff members don't experience the same pressures as their university colleagues, enabling Carnegie astronomers to focus more on their research. On the other

hand, he noted dryly, there's a downside to the working conditions at Carnegie Observatories: "Many of our staff members wouldn't last 10 minutes at other places."

Supernova sleuths

After a couple of days in Santiago, I took an hour-long flight past the highest peaks in the Andes to the lovely seaside resort of La Serena, where Las Campanas has its headquarters. There, Gaston Folatelli, a young Argentinean researcher, introduced me to the Carnegie Supernova Project.

Carnegie launched the effort in 2004. On virtually every good observing night of the year, astronomers use Las Campanas Observatory's suite of four telescopes to conduct detailed observations of supernovae. The project will continue for 5 years.

Folatelli is part of a team of astronomers that focuses on supernovae in nearby galaxies, or those within 1 to 2 billion light-years from Earth. The team's goal is to collect detailed data on some 200 exploding stars. Nearby supernovae burn brightest for a

1941

Walter Baade discovers the remnant of the supernova Kepler observed in 1604.

1949

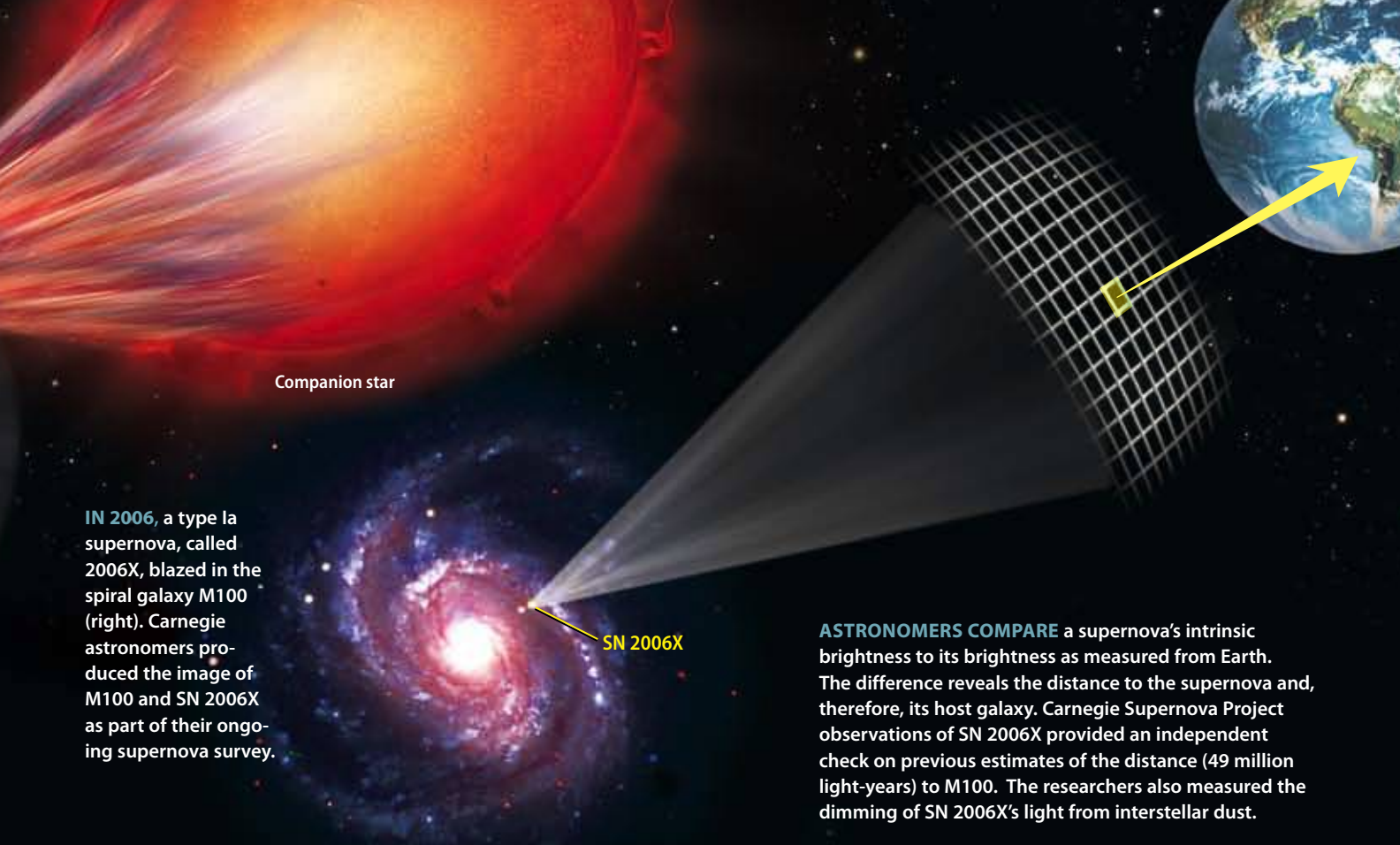
200-inch Hale Telescope at Palomar Observatory becomes operational; Hubble is first to use the colossal instrument.

1969

Carnegie Observatories acquires Las Campanas observing site.

1971

40-inch (1 meter) Henrietta Swope Telescope becomes first new instrument at the observatory on Cerro Las Campanas in Chile.



Companion star

IN 2006, a type Ia supernova, called 2006X, blazed in the spiral galaxy M100 (right). Carnegie astronomers produced the image of M100 and SN 2006X as part of their ongoing supernova survey.

SN 2006X

ASTRONOMERS COMPARE a supernova's intrinsic brightness to its brightness as measured from Earth. The difference reveals the distance to the supernova and, therefore, its host galaxy. Carnegie Supernova Project observations of SN 2006X provided an independent check on previous estimates of the distance (49 million light-years) to M100. The researchers also measured the dimming of SN 2006X's light from interstellar dust.

ASTRONOMY: ROEN KELLY; M100: LAS CAMPANAS OBSERVATORY/CARLOS CONTRERAS

week or two, so astronomers have to make the best of that opportunity. "Every week, a handful of new ones are discovered, and it's important to observe when they're at maximum light," Folatelli explains.

A second team, consisting of Freedman, her husband Barry Madore, and a half-dozen others, observes supernovae in the most distant galaxies visible from Las Campanas. They aim to conduct studies of about 100 such objects.

A variety of instruments feast on the precious photons collected by Las Campanas' telescopes, including CCD cameras, infrared detectors, and digital spectrographs. These instruments are delivering the most detailed and richest observations of their kind to date.

Although past studies of supernovae almost exclusively looked in the blue or visible portion of the spectrum, Carnegie is observing across the spectrum from infrared to ultraviolet. The data, Freedman promises, will prove unprecedented in their precision and accuracy. The supernova

project will not only increase our confidence that the accelerating universe is real, but hopefully provide the hard data needed to build theories to explain dark energy.

The finest seeing

After visiting with Folatelli, I left La Serena the next day in a rented car, northbound on the Pan-American Highway toward Las Campanas. Two hours later, deep in the desert, I turned onto a relentlessly climbing dirt road, passing wild burros and a strange hallucinatory half-squirrel, half-rabbit animal called the vizcacha. Cerro Las Campanas' broad summit, dotted with white domes, sat beneath deep blue skies.

That evening, after my visits with Madore, Kelson, and other Carnegie astronomers, I paused to take in the view on a catwalk outside one of the Magellan telescopes. The Milky Way was astoundingly brilliant, with richly mottled detail like in an airbrushed painting. Its thick brightness in Sagittarius scarcely diminished as it meandered south to Centaurus

and the Southern Cross. I stood there gazing up at the same Milky Way that the Maya and other Mesoamerican cultures regarded as the center of all existence.

When Carnegie founded his institution, the universe consisted of a single galaxy. Today's puzzles would have been incomprehensible. Who can imagine tomorrow's?

Venus was rising behind me that night as I went back toward my quarters, awed by how much there is still to learn. The universe's fundamental structure and its motion — sculpted by inconceivable forces of unimaginable power — took shape more than 13 billion years ago. Nothing we can ever do or discover can alter its destiny in the slightest. And yet we are driven to know it, incited to uncover its strange realities. The century-old Carnegie Institution seems particularly focused on the task — and uniquely capable of actually succeeding. ■

ONLINE EXTRA

Listen to an interview with Carnegie Observatories' Wendy Freedman at www.astronomy.com/toc.

1977

100-inch (2.5 meters) Irénée du Pont Telescope sees first light.

2000

First of two 21-foot (6.5 meters) Magellan telescopes sees first light; second instrument operational in 2002.

2001

Wendy Freedman and other members of Hubble Space Telescope Key Project report new value for universe's rate of expansion, using Hubble Space Telescope observations.

2004

Carnegie Supernova Project begins.

2016

Construction of 80-foot (24.5 meters) Giant Magellan Telescope scheduled for completion.

SEPTEMBER 07

Jupiter gleams in the evening

Anyone looking low in the southern sky after sunset will notice the brilliant beacon of Jupiter, the solar system's largest planet. Jupiter displays its turbulent atmosphere each night through a telescope, and you can easily follow its retinue of four constantly dancing moons. Invite your neighbors over for a jovian view they'll never forget.

40 Venus meets Saturn



65 Will Aurigid meteors erupt?



65 Watch Europa transit Jupiter



65 See the Moon's sunset scarp



66 When to view the planets



66 See the zodiacal light



67 View Pallas' southern dive



Visible to the naked eye

Visible with binoculars

Visible with a telescope



MERCURY GLEAMED in evening twilight during its February 2006 apparition. Unfortunately, September's event will be a considerable challenge for northern observers. PIETRO CARBONI

Two other giant planets arise later in the evening. Neptune resides in Capricornus, a constellation that rises in the southeast at sunset. Uranus, farther east in Aquarius, reaches opposition this month and provides a naked-eye challenge.

Mars is brightening in the morning sky as observers pre-

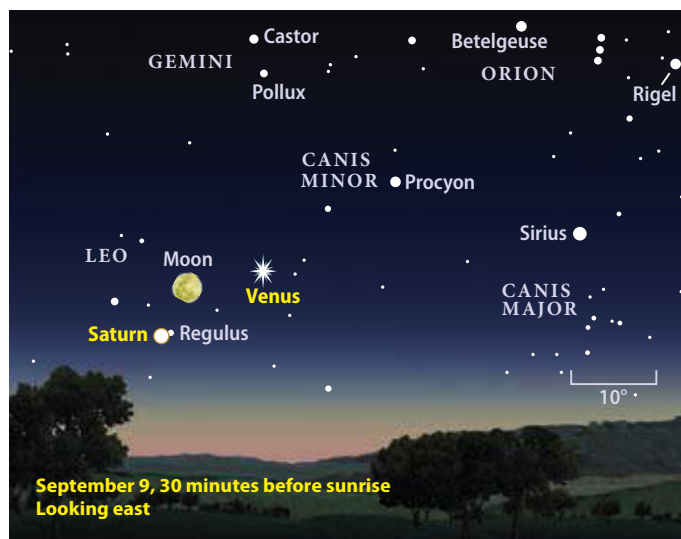
pare for this winter's brief Red Planet observing season. Venus and Saturn emerge into pre-dawn skies against the starry backdrop of Leo the Lion.

Before the sky darkens, a few skygazers might be lucky enough to spot **Mercury** in bright twilight. Unfortunately, it's the planet's worst evening apparition for the Northern Hemisphere this year, but it's an excellent one for those south of the equator.

On September 21, Mercury lies less than a Moon-width from Spica, the brightest star in Virgo. Observers with a flat western horizon, such as those in the Midwest and on the West Coast, have the best chance of spotting the pair.

Spica, shining at magnitude 1.0, will require binoculars to see, but Mercury is a full magnitude brighter and will be visible to the naked eye. The pair lies a couple of degrees above the horizon 30 minutes after sunset — a tough binocular

— Continued on page 65



VENUS, SATURN, Regulus, and a waning crescent Moon greet early risers September 9. Look for an even tighter pattern from the trio in early October. ASTRONOMY: ROEN KELLY

The all-sky map shows how the sky looks at
11 P.M. August 1
10 P.M. August 15
9 P.M. August 31

Planets are shown at midmonth

Quick fact

Earth is the solar system's densest planet. Mercury ranks a close second, and Venus takes third place.

ILLUSTRATIONS BY ASTRONOMY: ROEN KELLY

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.

- 01** Mercury passes 6° south of Pollux, 3 P.M. EDT

The Moon passes 2° north of Uranus, 10 P.M. EDT

03 The Moon is at perigee (229,218 miles from Earth), 7:54 P.M. EDT

05 Last Quarter Moon occurs at 5:20 P.M. EDT

06 The Moon passes 6° north of Mars, midnight EDT

12 New Moon occurs at 7:03 P.M. EDT

13 Perseid meteor shower peaks

Neptune is at opposition, 2 P.M. EDT

15 Mercury is in superior conjunction, 4 P.M. EDT

17 Venus is in inferior conjunction, midnight EDT
- 18** The Moon is at apogee (251,418 miles from Earth), 11:28 P.M. EDT

20 First Quarter Moon occurs at 7:54 P.M. EDT

21 Saturn is in conjunction with the Sun, 7 P.M. EDT

The Moon passes 0.7° south of Antares, 9 P.M. EDT

The Moon passes 6° south of Jupiter, 11 P.M. EDT

23 Mars passes 5° north of Aldebaran, 8 P.M. EDT

27 The Moon passes 1.4° south of Neptune, 5 A.M. EDT

28 Full Moon occurs at 6:35 A.M. EDT; total lunar eclipse

29 The Moon passes 2° north of Uranus, 5 A.M. EDT

30 The Moon is at perigee (226,296 miles from Earth), 8:12 P.M. EDT

Star colors

Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

How to use this map

This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Magnitudes

- Sirius

● 0.0

● 1.0

● 2.0

● 3.0

● 4.0

● 5.0
- Open cluster

⊕ Globular cluster

□ Diffuse nebula

○ Planetary nebula

○ Galaxy

— *Continued from page 40*
target. By sundown in San Francisco, Mercury has moved closer to Spica — only 23' separate them. Hawaii, farther south, is well placed to see Mercury 16' from Spica. From there, the pair remains 4° high 45 minutes after sunset.

Jupiter lies fairly low in the southern sky after dusk. Located within the constellation Scorpius, the planet's low arc makes it hard to get clear, crisp views because we're looking through the atmosphere's bulk instead of straight up. Sky-watchers in southern states are slightly better off than those in the north because objects near the southern horizon will appear slightly higher.

Jupiter stands about 6° from Antares, the magnitude 0.9 star in Scorpius. Antares, a red supergiant star, glows with an orange hue compared to the light reflected off Jupiter from our Sun, a yellow dwarf star. Take the time to notice their appreciable color contrast.

Jupiter makes up for its low altitude by its large apparent size through telescopes. This month, Jupiter's disk spans 37". The planet's broad, dark northern and southern equatorial belts, two prominent atmospheric features, stand out readily. The four bright moons — Io, Europa, Ganymede, and Callisto — almost always are on display. Sometimes, though, we can't see them because their orbits have carried them behind the planet or into its shadow, which now extends into space east of Jupiter's disk.

Martin Ratcliffe is the former president of the International Planetarium Society. **Alister Ling** is a meteorologist for Environment Canada.

Catch Jupiter well before it sets, which means observing an hour or so after sunset. On September 1, the planet sets around 1 A.M. local time. By month's end, Jupiter sets nearly 2 hours earlier and is visible only in twilight skies.

Pluto lies about 16° north-east of Jupiter, near the north-western limit of Sagittarius. At magnitude 14, Pluto's hard to spot, but CCD images of the region will have little difficulty recording it. You can find the correct region of sky by moving 8.8° west of M17, the Omega Nebula. Try in early September during moonless nights when Pluto is highest in the sky as darkness falls.

Within the constellation Capricornus lies the bluish disk of Neptune, now glowing at magnitude 7.8. It tracks west among these stars all month.

WATCH FOR AN AURIGID OUTBURST

This month's minor Alpha Aurigid meteor shower may give some observers a brief blast of activity. According to SETI Institute meteor expert Peter Jenniskens, Earth will run into the dust trail from C/1911 N1 (Kiess), a long-period comet. The encounter will create a 2-hour meteor outburst peaking at 4:36 A.M. PDT September 1.

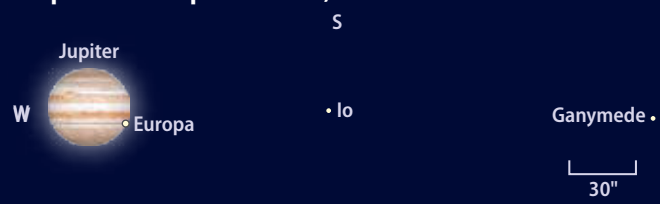
The timing favors western North America and Hawaii. A

waning gibbous Moon (76-percent lit) will wash out all but the brightest meteors.

Comet Kiess released the dust trail when it last rounded the Sun in 83 B.C. Jenniskens predicts as many as 3 Aurigid meteors a minute during the outburst.

The meteors appear to radiate from a point near the bright star Alpha Aurigae (better known as Capella), hence the shower's name.

Jupiter on September 8, 9:20 P.M. EDT



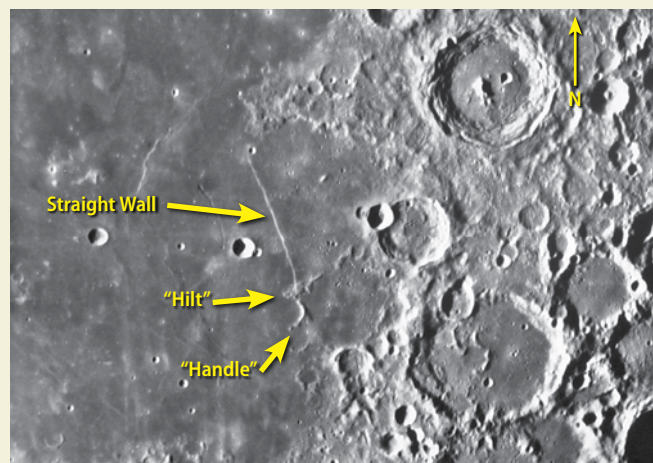
WATCH EUROPA glide across Jupiter's cloudy disk September 8. The giant planet moves into twilight by month's end, so observe Jupiter early in the month. *ASTRONOMY: ROEN KELLY*

SEE THE MOON'S SUNSET SCARP

The Straight Wall is the Moon's best-known scarp. Most often seen just after First Quarter, the feature looks like a sharp black line. But the Straight Wall (officially, Rupes Recta) looks different near sunset.

With the slope facing the Sun just after Third Quarter, the Straight Wall transforms into the unmistakable figure of a sword. The bright white line of its blade terminates on the south end with a hilt and handle, thanks to a chance placement of some hills and a half-buried crater.

The Straight Wall is 75 miles long and rises some 1,300 feet above the surrounding plain. Scientists believe the scarp likely formed when the lava of Mare Nubium cooled and subsided.



LOOK FOR THE STRAIGHT WALL in the shallows of Mare Nubium just north of where the terrain abruptly rises to the bright southern highlands. *CONSOLIDATED LUNAR ATLAS/UJA/LPL*

The Pleiades occultation September 3 provides the perfect encouragement for you to view the Moon after midnight. Sunset at the Straight Wall returns October 2 and 3. Seeing the Straight

Wall's sharp shadow after sunrise (look September 19 and 20), observers concluded the feature was a cliff. In fact, it slopes between 12° and 20°. It's a steep grade, but no cliff.

/// WHEN TO VIEW THE PLANETS

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (west)	Mars (northeast)	Venus (east)
Jupiter (south)	Uranus (south)	Mars (southeast)
Uranus (east)		Saturn (east)

On September 1, the solar system's eighth planet lies 2.5° northeast of Iota (ι) Capricorni, a magnitude 4.2 star in the constellation's northeastern part. Neptune culminates — that is, reaches its greatest altitude — in the south around midnight local daylight time.

Uranus reaches opposition September 9 in Aquarius. In a couple of years it will reach aphelion, its farthest point from the Sun. So, this year, the seventh planet is almost as distant as it can be. At opposition, it lies 1.78 billion miles away. The

orbital plane of its satellites and rings now lies almost edge-on to Earth. Exact alignment occurs later this year, when Uranus reaches its December 16 equinox. Then, the planet's equator will bisect Uranus' visible disk.

Uranus is technically visible to the unaided eye, but only under the best dark-sky conditions and only if your eyesight is excellent. Use Phi (φ) Aquarii as a guide. It glows at magnitude 4.2. On September 1, magnitude 5.7 Uranus lies 0.3° northwest of this star.

During the month, Uranus pulls away from Phi. On September 8, the seventh planet lies about one Moon-width (0.5°) west of the star. A nearly Full Moon lies 7° west of Uranus September 25 and hops the same distance to its east the following night.

A telescope will show a tiny bluish-green disk, clearly not starlike, less than 4" across. As a consequence of this month's opposition, Uranus is visible all night. The planet sets in the southwest as the Sun rises.

"**Mars** season" is approaching fast, but this will not be one of the Red Planet's best years. But as September begins, you'll see a grand sight as Mars rises: Taurus the Bull glares with two red eyes. Mars lies about 8° northeast of Aldebaran, and the two rise together shortly after 11:30 P.M. local daylight time.

Mars shines at magnitude 0.3, half a magnitude brighter than Aldebaran, at 0.8. During the early morning hours of September 3, the Last Quarter Moon hides some of the stars of the Pleiades as Mars and Aldebaran look on.

Mars moves eastward through Taurus, and the Red Planet passes between the Bull's horns September 17. Mars will swing back to this point in late January next year as it concludes its retrograde path.

Mars brightens to magnitude 0.0 September 25, when it lies 15° due north of another of winter's reddish stars, Betelgeuse in Orion. Mars crosses into Gemini at month's end.

Mars' disk grows to an apparent size of 9" by September's third week. This is when most telescopes will begin to show surface features. It's

COMET AND ASTEROID DUST ALL AGLOW

Unimaginably vast numbers of dust specks pervade the solar system. They're insubstantial — 50 to 100 times smaller than a human hair's width. Nevertheless, you can detect these particles' combined glow before sunrise on a crisp, moonless September morning.

Just as dust and pollution particles brighten the sky around the Sun, interplanetary motes also scatter sunlight. Astronomers call this glow the zodiacal light because it stretches along the zodiac — the same strip of sky where the planets hang out.

The diffuse light forms a triangular wedge that looks like a large, slanted pyramid. The base occupies the northeastern horizon, and the wedge tilts to the upper right, passing below Castor and Pollux in Gemini and the Pleiades in Taurus.

The zodiacal light is one of those "can't see the forest for the trees" phenomena. Once you recognize it, the glow is surprisingly easy to see. But most people simply mistake it for the approaching dawn or the artificial skyglow of a distant town.

Wait until after the 9th, when there's minimal interference from moonlight. Find a location well to the east of any large city or town. Scan the northeastern sky about two and a quarter hours before sunrise — well in advance of the dawn's early light. Remember you're looking for a veil-like glow that is quite large, covering two full spans of your outstretched hands.

Most dust comes from asteroids and comets in the inner solar system. But recent research indicates some particles arise from distant Kuiper Belt bodies.



THE "FALSE DAWN," or zodiacal light, is a triangular glow made from asteroid bits and comet crumbs. Try observing it after September 9, when the Moon doesn't interfere. TONY AND DAPHNE HALLAS

springtime in Mars' northern hemisphere, so neither polar cap preferentially tilts our way.

The planet's phase is most distinctive as Mars passes through quadrature September 17. Quadrature means that the angle between Earth, Sun, and Mars is exactly 90°. As a result, Mars appears at its highest in the southern sky at dawn.

Look for the Red Planet's noticeable 86-percent phase through a telescope — Mars is clearly not the perfect circle it will become at opposition. On September 25, Mars lies as close to Earth as the Sun, but, by December's opposition, it will halve this distance.

The main Mars observing period will be from October through February next year. Since the next two Mars oppositions will be worse than this one, make the most of it. The Red Planet's best opposition this decade was back in August 2003. Mars won't give observers that good a show again until the 2016 opposition.

Venus begins a rapid climb into the eastern sky before dawn. On September 1, the planet rises at 5:30 A.M. local time. Four weeks later, Venus rises by 4 A.M. Watch the slim crescent fatten throughout the month, changing from a slender 8-percent to 33-percent lit. As this is happening, the crescent's apparent angular size shrinks from 53" to 35" across. On September 8, a waning Moon joins the planet. Venus reaches greatest brilliancy September 23, when it shines at magnitude -4.8 .

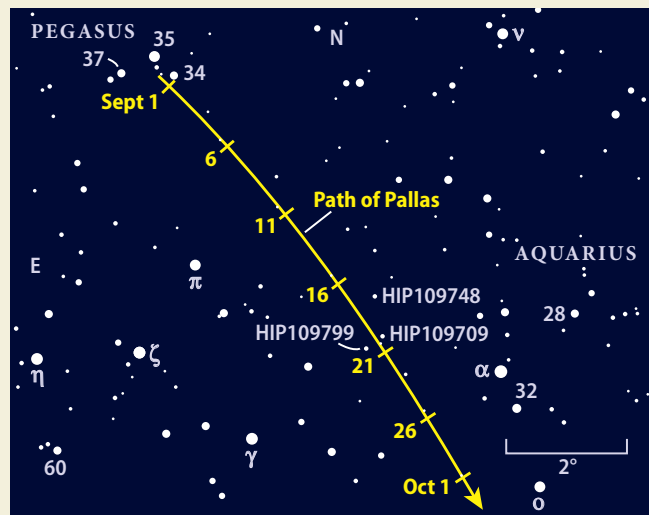
Joining Venus in the morning sky, **Saturn** reappears after its conjunction with the Sun. On September 1, in bright twilight, Saturn lies 0.8° north of

PALLAS TAKES A PLUNGE

Diving silently in front of Aquarius' distinctive Water Jar asterism, the large asteroid 2 Pallas is easy to track. This space rock is outside the range of binoculars from a suburban backyard, but a 3-inch scope can pull it into view.

Pallas reaches its peak brightness this year — magnitude 8.7 — September 2/3. By midevening, the top of Aquarius is about a third of the way up the southeastern sky. There are few stars here that outshine Pallas, but several gleam with similar brightnesses. Make a quick sketch of the star field, then return the next night to see which dot shifted.

If you've just set up outside, let your scope cool down so its optics can deliver the best image. After a peek at Pallas, set your sight on Zeta (ζ) Aquarii, a tight double star with a 2.3" gap between its 4.3- and 4.5-magnitude components. Use up to 50x magni-



CATCH ASTEROID 2 Pallas as it courses south through Aquarius the Water-bearer. ASTRONOMY: ROEN KELLY

fication per inch of aperture if the atmosphere appears steady enough to support it.

Pallas was the second asteroid discovered, hence its catalog number. Ceres, the first asteroid found, is 560 miles wide, so Pallas' 300-mile girth makes it second in size, too.

Most asteroids circle the Sun in roughly the same plane

as Earth and the other planets, but something happened a long time ago that knocked Pallas out of whack. The asteroid's high-inclination orbit takes it as far north as Hercules.

Pallas plunges through the ecliptic this year, then bottoms out in Columba in late 2008. That's south of Lepus, the celestial hare beneath Orion's feet.

Regulus, the brightest star in Leo. Use binoculars to spot the pairing in the fast-brightening twilight. Saturn climbs higher each morning, and, by September 30, rises shortly after 4:30 A.M. local time; by then, the ringed planet has moved 3.5° east of Regulus. On the same night, Venus lies nearly 7° west of the star. Both planets will make a fine appearance next month as they close the angular gap between them.

A **partial solar eclipse** occurs September 11. The Moon's shadow will fall over Antarctica and South America. Nearly the entire South American continent south of Ecuador sees some part of the event.

This month, the Sun's annual journey along the ecliptic carries it south across the celestial equator. This yearly passage marks the autumnal, or



MARS RISES with ruddy Aldebaran in Taurus the Bull this month. On the morning of September 3, look for the orange pair beneath the Pleiades and a gibbous Moon. ASTRONOMY: ROEN KELLY

fall, equinox in the Northern Hemisphere, but it's the astronomical start of spring in the Southern Hemisphere. Whatever the new season will be

where you live, it begins September 23 at 5:51 A.M. Eastern Daylight Time, when the Sun's center slips into the southern celestial hemisphere. ■

One of the sky's greatest showpieces reveals a snapshot of the solar system's future. /// BY RAYMOND SHUBINSKI

All about the Dumbbell Nebula

When French comet-hunter Charles Messier (1730–1817) discovered the Dumbbell Nebula (M27) in 1764, he had no idea this object — one of the sky's brightest planetary nebulae — foretold our Sun's fate. Nearly 200 years would pass before astronomers realized our star

someday will become an object similar to the Dumbbell Nebula.

I have observed Messier's 27th object for decades with every type of telescope, and it has never looked like its namesake to me. I've always seen something different. Growing up in the late 1950s and early 1960s, comic books were an everyday reading adventure, and Batman was near the top of

my list. When I look at M27, I see the Bat Signal that flashed across the clouds of Gotham City. Like the Bat Signal, this tiny fuzzy object beckons from the depths of the constellation Vulpecula.

Observing the Dumbbell

Vulpecula the Fox was one of seven constellations invented by 17th-century Polish

SMART FACTS ABOUT THE DUMBBELL NEBULA

Object type: Planetary nebula

Other names: M27, NGC 6853

Constellation: Vulpecula

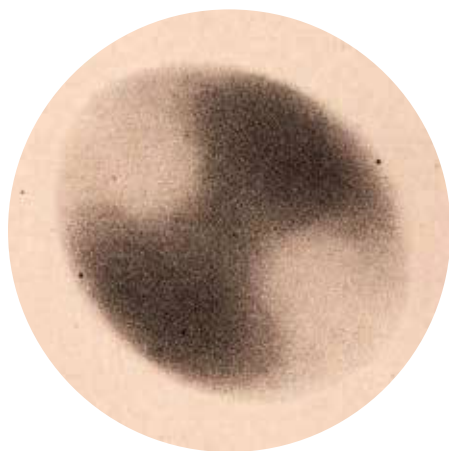
Right ascension (2000.0): 19h57m

Declination (2000.0): 22°43'

Size: 8' by 5.7'

Magnitude: 7.3

Estimated distance: 1,250 light-years



AN EARLY SKETCH of the Dumbbell Nebula shows the shape most familiar to observers. Sketching at the eyepiece is a great way to improve your observing skills. This drawing by English astronomer John Herschel (1792–1871) appeared in the *Philosophical Transactions of the Royal Society*, Vol. 123, 1833. LINDA HALL LIBRARY OF SCIENCE, ENGINEERING, AND TECHNOLOGY



AT FIRST GLANCE, this sketch of the Dumbbell Nebula doesn't look "dumbbell" in shape. Look closer, however. French astronomer Étienne Léopold Trouvelot (1827–1895) made this sketch, which appeared in the *Annals of the Observatory of Harvard College*, Vol. 8, 1876. Trouvelot's drawing shows the dumbbell and this object's outer nebulosity. MICHAEL E. BAKICH LIBRARY

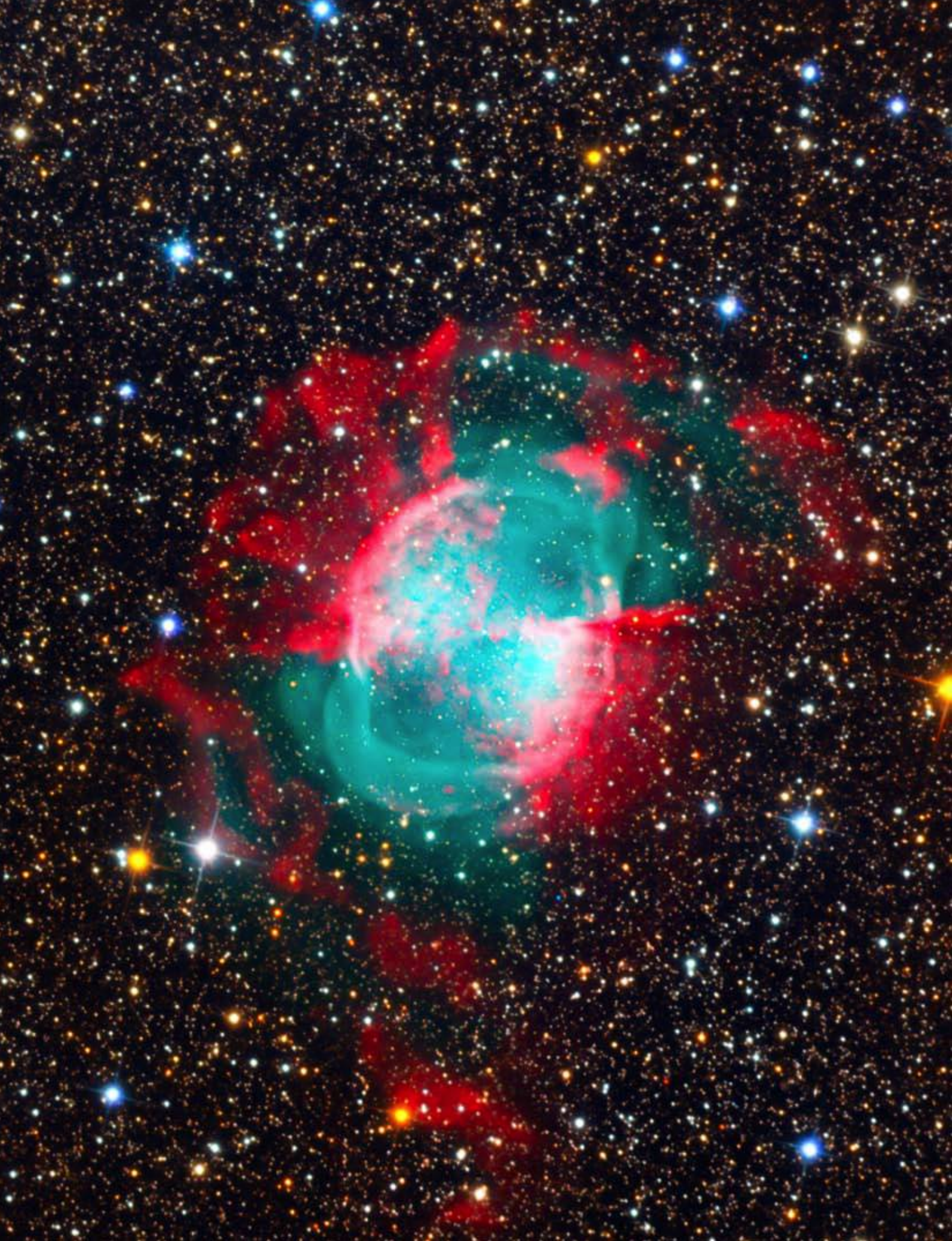
astronomer Johannes Hevelius (1611–1687). This constellation came into the news when graduate student Jocelyn Bell discovered the first pulsar there in 1967.

This small constellation, which ranks 55th in area out of the 88 constellations, boasts only the Dumbbell as its lone Messier object. Vulpecula reaches the point opposite the Sun July 25, making it a true summer constellation. Because Vulpecula lies along the Milky Way's summer path, M27 is seen not only against a rich background of stars, but at times appears almost three-dimensional because it is surrounded by foreground stars as well.

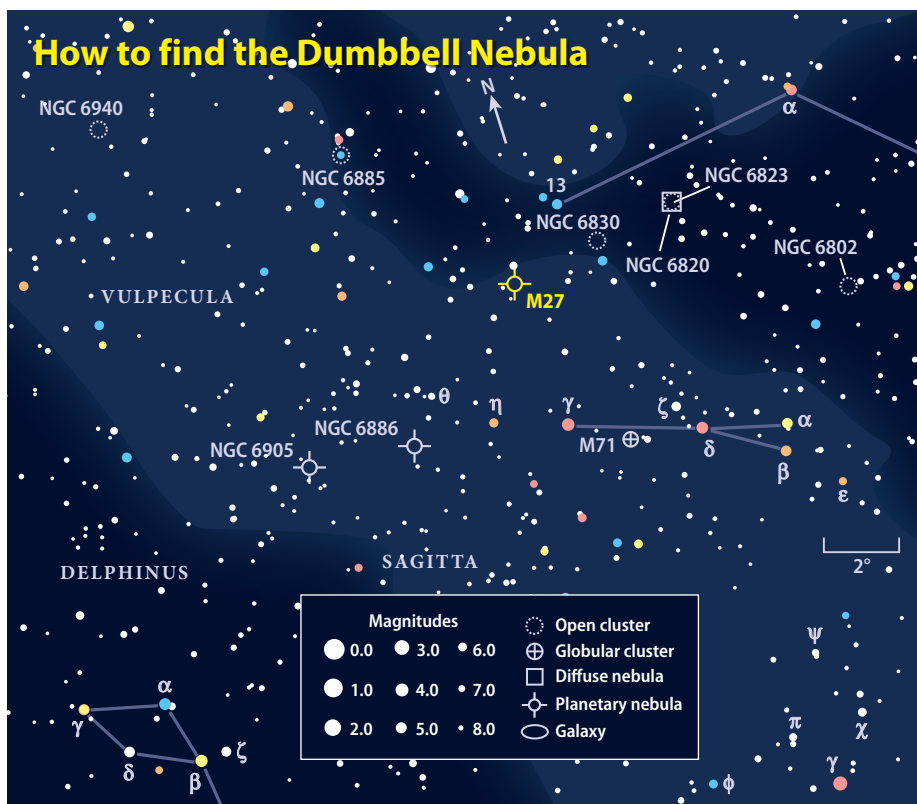
M27 is an easy object to view because it glows at magnitude 7.4 and is rather large.

— Continued on page 71

► THIS DEEP EXPOSURE of the Dumbbell Nebula (M27) reveals the planetary nebula's seldom seen outer gas shell. The red in this image comes from hydrogen atoms that have absorbed ultraviolet radiation and reemitted it as visible light. The green originates from doubly ionized oxygen. M27 lies in a densely packed, colorful Milky Way star field. TONY AND DAPHNE HALLAS







USE THIS CHART to locate the faint constellation Vulpecula the Fox. The Dumbbell Nebula (M27) lies 3° north of magnitude 3.5 Gamma (γ) Sagittae. ASTRONOMY: RICHARD TALCOTT AND ROEN KELLY

— Continued from page 68

It measures 8' by 5.7', about $\frac{1}{15}$ the area of the Full Moon. The Dumbbell can be seen through binoculars and is an easy target for a small telescope. M27 was the first planetary nebula discovered. Messier found it July 12, 1764. His interest lay in comet-hunting, and, indeed, M27 looks comet-like at low power. Many amateur astronomers have similarly identified the Dumbbell as a comet at first glance.

Historical notations

The name “Dumbbell” goes back to a written description made by the early 19th-century British astronomer John Herschel (1792–1871), who also likened M27’s shape to a “double-headed shot.” Other observers have described it as having an hourglass

◀ **THIS FALSE-COLOR IMAGE** of the Dumbbell Nebula emerged when astronomers used the 3.5-meter WIYN telescope at Kitt Peak National Observatory in Arizona. They combined exposures taken through three narrowband filters: The red color displays Hydrogen-alpha emission at 656.3 nanometers; green shows doubly ionized oxygen emission at 501 nm; and the faint blue hues originate from neutral oxygen emission at 630 nm. GEORGE JACOBY/WIYN/NSF

shape. Am I the only one who sees the Bat Signal? Let me know by sending your observing comments to me at rshubinski@unionstation.org.

I find it fun and instructive to look back at the descriptions provided by observers who predate photography. Messier himself noted this object “appears in an oval shape; it doesn’t contain any stars.”

Sir William Herschel (1738–1822), the discoverer of Uranus, was convinced that almost all nebulae could be resolved into stars under the right conditions and with a powerful enough telescope. For Herschel, M27 was “a double stratum of stars of a very great extent.”

In the 1881 edition of the observing classic *A Cycle of Celestial Objects*, Admiral William Smyth postulates that M27 may be a multiple nebula rather than a single object: “In my instrument, however, M27 shows several, of which three, lying sp [south, preceding] and nf [north, following], nearly in the same direction with the dumb-bell, and 26s distance, are sufficiently remarkable.”

In *Pleasures of the Telescope*, published in 1901, Garrett P. Serviss states M27 is “worthy of attention.” Serviss tells us that, with a 5-inch refractor, “We are able to per-



THE TWO MICRON All-Sky Survey (2MASS) imaged the Dumbbell Nebula but revealed only a ghostly red glow. The red color in this image comes from molecular hydrogen (H_2), which emits radiation at 2.12 microns. Planetary nebulae like the Dumbbell emit radiation primarily in visible wavelengths. 2MASS

ceive that it consists of two close-lying tufts of misty light.” Serviss also says recent photographs taken with the Lick Observatory telescope show “that its structure is spiral.”

Many observers have made note of M27’s greenish tint. Thomas W. Webb, another 19th-century observer, described M27 as “two hazy masses in contact.” Webb also mentions that the two masses have a narrow zone between them.

American amateur astronomer and author John Mallas (d. 1975) points out that M27 is “almost uniform in brightness ... is well defined, though the ends of the major axis are fuzzy and uneven.” Mallas also notes, as have others, that M76 in Perseus, which appears smaller and fainter, has a dumbbell shape as well.

Classifying the Dumbbell

M27 belongs to a class of objects known as planetary nebulae. For 21st-century amateurs who know basic astronomy, this may sound contradictory. These nebulae have nothing to do with planets or planetary formation. This misnomer extends to the late 18th century and English astronomer William Herschel.

On March 13, 1781, Herschel discovered Uranus while observing with a small telescope he had made himself. Through his scope, what turned out to be a new planet appeared fuzzy. In fact, Herschel was convinced he had discovered a comet, and it was some months before astronomers realized the object’s true nature.



THIS HUBBLE SPACE TELESCOPE close-up image of the Dumbbell Nebula shows many knots. Some look like fingers pointing at the central star, located just off the upper left of the image. Others are isolated clouds, with or without tails. Their sizes typically range between 11 and 35 billion miles (17 and 56 billion kilometers). The knots form at the interface between the nebula's hot and cool parts. NASA/THE HUBBLE HERITAGE TEAM (STScI/AURA)

Herschel's discovery propelled him to fame and fortune, and provided the time and money to build bigger and better telescopes. In his description of Messier's object, he said M27's greenish color and round shape reminded him of Uranus' appearance at the time of its discovery. He, therefore, coined the name "planetary nebula." Other Messier objects, such as the Ring Nebula (M57), have an even more "planetary" appearance.

Did astronomers of the past take the name planetary nebula to reflect reality? Did they believe they were seeing the embryonic stages of solar system formation? In fact, they did, and it took years of observation and study to realize the truth of the matter.

In Herbert A. Howe's 1896 book, *A Study of the Sky*, the last chapter is thorough proof that astronomers regarded planetary nebulae, spiral nebulae, and other objects as snapshots of creation.

Howe reflects, "Pass in review hundreds of planetary nebulae. Are they not circular? Have not some of them faint condensations in their centers? Can we not arrange known nebulae in orderly sequence from those composed of the dimmest world-stuff up to those which have just received the appellation of nebulous stars? Is the testimony of

Ray Shubinski is a contributing editor of *Astronomy* who loves historical astronomy and observing planetary nebulae.

the nebulae inconclusive?" Howe continues with a long stream of rhetorical questions, all of which later research proved to be completely misguided.

Such speculation was driven in large part by 18th-century German philosopher Immanuel Kant (1724–1804). Kant had developed the nebular hypothesis of solar system formation (where the Sun and planets formed from a rotating, collapsing nebula) long before much observational data was available to support the idea. It turns out that, in the broad strokes of his ideas, Kant was not far from the mark.

The frontispiece of American author Martha Evans Martin's 1901 book, *The Dance of the Planets*, features a picture of the Whirlpool Nebula (M51), now known to be a distant, face-on spiral galaxy. The caption under the photograph gives a detailed explanation of how this nebula is evolving into a new system of planets!

Even Sir Robert Ball (1840–1913), one of England's most renowned astronomers, invoked visions of the nebular hypothesis as he talked about planetary nebulae in *The Story of the Heavens* from 1886. "It is, however, impossible to view the annular nebulae without being reminded of those elegant objects known as vortex rings," he wrote.

American astronomer Edwin Hubble (1889–1953) finally figured out that the vast majority of observable nebulae are not multiple stages in the formation of solar systems. In the majority of cases, they rep-

resent distant "island universes," an early 20th-century term astronomers have replaced with "galaxies."

Dumbbell Nebula science

A man whose name means "shining" in Sanskrit finally resolved the problem of planetary nebulae and led the way to a full understanding of stellar evolution from brown dwarfs to black holes. Born in 1910 in Lahore, India, Subrahmanyan Chandrasekhar became one of the 20th century's greatest physicists.

In the early 1930s, Chandrasekhar developed the physics that explains the threshold at which stars can either bear their own weight or collapse. For astronomers, the most important factor is mass. The Chandrasekhar limit demonstrates that a star of up to 1.4 solar-masses can fuse hydrogen into helium for nearly 10 billion years. Later, as the helium fuses into carbon, the star will begin to collapse.

As telescopic imaging became more sophisticated and spectroscopy allowed astronomers to "sample" the chemistry of planetary nebulae, most revealed hot, dense stars at the centers of expanding shells of gas. At the heart of the Dumbbell Nebula lies a star with a visual magnitude of 13.5. The surface temperature of this object, however, is 85,000 K. Compare that to our Sun's more temperate 6,000 K.

Some 50,000 years ago, the star at M27's center reached its Chandrasekhar evolutionary limit and began to collapse. At the end of its life cycle, a star about the mass of our Sun swelled into a bloated red giant



AMATEUR ASTRONOMERS often target the Dumbbell Nebula. This image combines unfiltered, red, green, and blue exposures totaling 130 minutes. JOE AND GAIL

METCALF/ADAM BLOCK/NOAO/AURA/NSF



THE EUROPEAN SOUTHERN OBSERVATORY'S Very Large Telescope at the Paranal Observatory in Atacama, Chile, provided astronomers this exceptional image of M27. This three-color composite combines a short exposure through a wide-band blue filter

with exposures through two interference filters: doubly ionized oxygen and atomic hydrogen. The images were color-coded as blue, green, and red, respectively, and combined to produce this picture that shows the nebula's structure in approximately true colors. ESO

many times its original diameter. Eventually, the star's final demise began. At its core, carbon and oxygen formed, and the star's energy source shut down.

Sometime later, a rebound from the collapse occurred and expelled about 50 percent of the star's mass into space. This event created a planetary nebula with an intensely hot white-dwarf star at its center. Unlike the Ring Nebula (M57), we see the Dumbbell at an angle that hides the ring-like structure. M27's central star's temperature surpasses that of most white dwarfs. Astronomers classify the star as a subdwarf.

The best estimate of M27's distance is 1,250 light-years. If this distance is correct, then M27 measures about 3 light-years across. The central star emits ultraviolet radiation (UV), which excites the gas atoms in the expanding shell. Those atoms can't hold the energy for long, however. They soon reemit it as visible light.

M27's greenish tint shows up even through amateur telescopes. UV radiation strips electrons from oxygen atoms in a process called ionization. Those atoms reemit the energy as green light with a wavelength of 500.7 nanometers. You can

purchase eyepiece filters labeled "OIII," which isolate this wavelength. Such a filter will enhance your view of M27.

It's a sobering thought that, in about 5 billion years, our Sun will have gone through the same process as M27's central star and be a white dwarf. As the Sun becomes a white dwarf, the expanding shell of hot gas will burn Mercury, Venus, Earth, and perhaps Mars, to cinders. Any life on Earth or Mars will be vaporized. Outside the solar system on far-flung planets, alien sensory devices may detect the event as a minor fluctuation in the cosmos. ■

ASK ASTRO

This month:

- Can a nuclear explosion break apart an asteroid?
- Do black holes ever disappear?
- What happens to water when it's released into space?
- Will the universe expand forever?

ASTEROID BLAST

Q: Could a nuclear explosion break apart an earthbound asteroid? — **BOB WILSHUSEN**, BLAINE, MINNESOTA

A: Yes, humankind has the capability to shatter, even vaporize, a small asteroid with a nuclear explosion. However, the effectiveness of blasting apart an asteroid depends on its size, internal structure, and where the bomb is placed.

How big an asteroid could we blast apart? A 475-kiloton nuclear warhead probably could shatter a 0.6-mile-wide (1 kilometer) asteroid headed toward Earth.

On a small asteroid — where the surface gravity is measured in thousandths, or even millionths, of Earth's gravitational field — a nuclear device simply resting on its surface probably wouldn't shatter the rocky object.

Using nuclear weapons to break apart or deflect an asteroid is an unpredictable undertaking. It would be difficult to create a tunnel for the bomb, especially in near-zero gravity conditions. The rock structure of the asteroid would probably not be known beforehand, adding to the complexity of tunneling.

The outcome is unpredictable because such an explosion has never been done. And

once the asteroid is broken apart, the resulting shotgun blast of smaller asteroid bits would travel on uncontrollable collision courses with Earth. Finally, international treaties ban the use of nuclear weapons in space. — **DANIEL D. DURDA**, SOUTHWEST RESEARCH INSTITUTE, BOULDER, COLORADO

DISAPPEARING BLACK HOLE

Q: Do black holes ever disappear? — **LARISA BALLADARES**, QUEENS, NEW YORK

A: Black holes consume everything that gets too close, so it may come as a surprise that they emit radiation.



NUKING AN ASTEROID might not remove its threat to earthlings. Such an explosion would break apart the space rock, but it wouldn't stop the fragmented asteroid bits from continuing to travel on earthbound collision courses. **DANIEL D. DURDA** (SOUTHWEST RESEARCH INSTITUTE)

Astrophysicist Stephen Hawking argues black holes slowly evaporate as they emit radiation. Particle/anti-particle pairs, often referred to as virtual particles, can literally pop into existence out of the vacuum. Astronomers have calculated and observed the effects of these virtual particles, or “vacuum fluctuations.”

Hawking explored the effects of the strongly curved space-time near a black hole’s event horizon on virtual particles. For example, if a pair of virtual particles pops into existence near the event horizon, and one particle of the pair falls across the event horizon, the other can escape and become a “real” particle. Because the virtual anti-particles did not have a chance to “annihilate” and give their energy back to the vacuum, in order to conserve energy in this process, the energy of the escaping particle must come from the black hole. This energy represents a tiny bit of the black hole’s mass.

Hawking argues that black holes slowly evaporate as they produce this quantum-inspired radiation, now commonly referred to as “Hawking radiation.” Hawking suggests this evaporation process causes black holes to lose mass and shrink in size.

—TOD STROHMAYER, NASA/GODDARD SPACE FLIGHT FACILITY, LAUREL, MARYLAND

IN THE KNOW

SUBLIMATE

The transition of a solid substance evaporating into a gas without passing through a liquid phase.

EVENT HORIZON

The boundary around a black hole from which, once crossed, light or matter cannot escape.

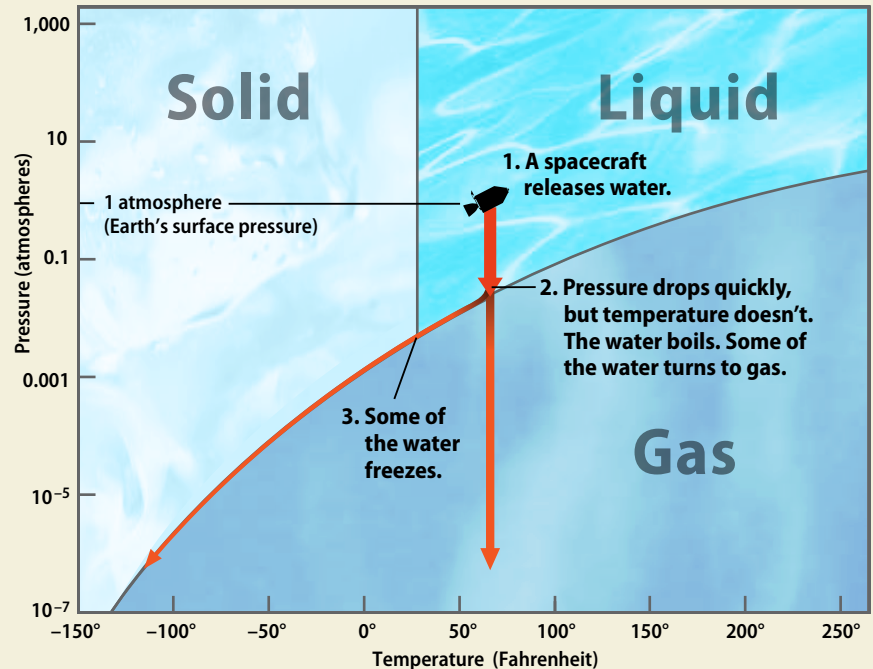
BLACK HOLE

A region of space where gravity is so powerful that not even light can escape.

DARK ENERGY

A type of “negative gravity” that seems to play a role in the acceleration of the universe’s expansion.

Solid, liquid, or gas?



WATER CHANGES from liquid to a solid or gas with changes in pressure and temperature. Most of the water released into space from a spacecraft immediately boils and turns to gas. Water that cools to 32° F (0° C) before turning to a gas freezes. MATTHEW STONEKING (LAWRENCE UNIVERSITY)

WATER IN SPACE

Q: Would water released from a spacecraft into space boil because of the low pressure or freeze due to the low temperature? — DAN McDERMID,

CHILLIWACK, ALABAMA

A: Both. When released into space, water boils until it freezes. Space is cold, about -454° F (-270° C). Even though the water may be cool when released into space, it will boil immediately because of the nearly non-existent atmospheric pressure.

As the water boils, most of it turns to gas. Any water that cools to 32° F (0° C) before sublimating would turn to ice.

— MATTHEW STONEKING, LAWRENCE UNIVERSITY, APPLETON, WISCONSIN

INFINITE EXPANSION

Q: Does the fact that our universe is accelerating imply that it will expand forever?

— NORMAN PHILLIPS, BRANCHVILLE, NEW JERSEY

A: We don’t know why the universe’s expansion is accelerating. This accel-

eration may be propelled by some form of “dark energy” that has negative pressure and, therefore, is a repulsive gravitational force. If dark energy is Einstein’s famous “cosmological constant,” then the universe will expand forever.

However, it is possible that dark energy is associated with some field that varies in time. In this case, it is unknown whether the universe will expand forever.

The current observational constraints are consistent with Einstein’s cosmological constant (and accelerated expansion forever). — MARIO LIVIO, SPACE TELESCOPE SCIENCE INSTITUTE, BALTIMORE

COMING NEXT MONTH ...

Will Pluto ever collide with Neptune or Uranus? Post your comments about this question online at www.astronomy.com/forums.

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P. O. Box 1612, Waukesha, WI 53187.

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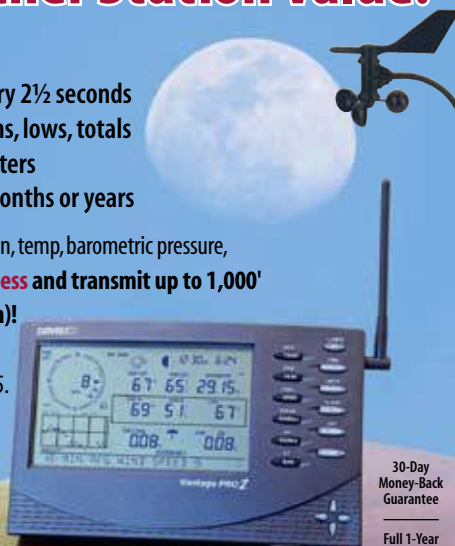
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STAR TREKS

You don't have to travel as far as you might think to get spectacular views through a telescope. /// BY LAURA LAYTON

Visit your friendly neighborhood observatory

Some of the best-known observatories are situated in remote, dark-sky locations high on mountaintops or deep in the desert southwest. But you might be surprised to learn you don't have to travel to such far-flung locations to experience the wonders of the cosmos. Many

observatories exist in urban and suburban locations, and there's likely one within driving distance of your home.

I had no trouble finding observatories that share astronomical concepts and knowledge with amateur astronomers and the community through a variety of activities. Whether they're full-blown educational programs, extensive observing

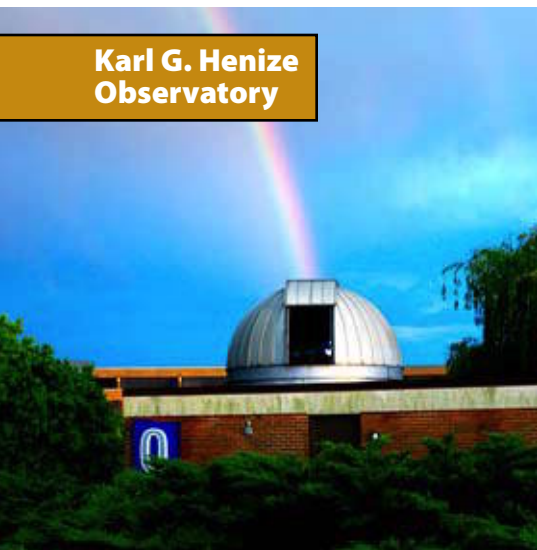
sessions, or Friday-night sky tours, these many neighborhood observatories, like the ones mentioned below, offer opportunities to enjoy the night sky throughout the year. Explore your own community to learn more about the astronomical offerings close to your home.

The Cincinnati Observatory Center

Touted as the oldest professional observatory in America, The Cincinnati Observatory Center was founded in 1842 by American astronomer Ormsby MacKnight Mitchel (1810–1862). This historic landmark features the world's oldest continuously working telescope: the 11-inch Merz und Mahler refractor, built in 1842. It also houses a 16-inch Alvan Clark and Sons refractor, built in 1904, and several smaller scopes.

The facility offers a comprehensive program of daytime and nighttime observing events, educational programs, tours, free lectures, and telescope viewing. Unlike many observatories, The Cincinnati Observatory Center doesn't close when the weather gets bad. When clouds or rain prevent telescope viewing, presenters hold extended question-and-answer sessions and offer tours of the two observatory buildings and their historic scopes. Daytime visits feature solar observing, using white-light and hydrogen-alpha fil-

Karl G. Henize Observatory



A RAINBOW appears to rise over Karl G. Henize Observatory in Palatine, Illinois. A dedicated observatory staff struggles with light-pollution and cloudy skies, due to the observatory's proximity to Chicago. PERCY MUI

Karl G. Henize Observatory



FRIENDLY STAFF members at the Observatory keep amateur astronomers coming back for more. Pictured here (front row) are volunteer Jamie Herold, staff member Amie Shadlu, volunteer Coralie Jackman, and volunteer Julie Gordon; (second row) staff member Jim Carney, volunteer and astronomy-club president Greg Gordon, and observatory director Percy Mui; (third row) staff member Larry Pavell. ALEX WOTAL

ters to look at the Sun, and lunar viewing near the Last Quarter Moon.

The center also offers an education program that can be customized for kindergarten through 12th-grade students, college students, civic groups and clubs, and astronomy teachers.

The Cincinnati Observatory Center



HISTORIC ROOTS and a comprehensive education and public outreach program are the hallmarks of The Cincinnati Observatory Center. The center's main building is shown here in 1999. The observatory was designated a national historic landmark in 1997. THE CINCINNATI OBSERVATORY CENTER

Karl G. Henize Observatory

The Palatine College campus in Palatine, Illinois, located 27 miles (43 kilometers) west of Chicago, is where you'll find the Karl G. Henize Observatory. Its suburban location means skyglow is an issue, but this doesn't keep the observatory's staff from opening its dome on a regular basis.

A friendly, knowledgeable staff makes this the little observatory that keeps astronomy buffs coming back. Observatory Manager Percy Mui greets many guests by name, helps astronomy students through

their class assignments, operates telescopes when time permits, and coordinates observatory staff members and volunteers.

Jim Carney operates the observatory's 14-inch Schmidt-Cassegrain go-to telescope during many public observing sessions, held every other week from March through November. Carney has observed the sky for some 60 years.

Another Henize Observatory staff member, Larry Pavell, has a keen interest in rockets. He often visits schools and shows kids the finer points of rocket building.

Staffer Walter Trentadue's involvement in all things astronomical spans decades. Positions he's held include staff member at Chicago's Adler Planetarium, board member of the Chicago Astronomical Society, vice-chairman of the Astrofest star party, and vice-president of the Prairie Skies star party.

The Henize Observatory crew has the knowledge and experience that make for a fun-filled and educational evening.

BCC Planetarium and Observatory

Brevard Community College (BCC) in Cocoa, Florida, is home to the BCC Planetarium and Observatory. It offers something for everyone interested in astronomy. Sky shows, public observing, 5,000 square feet (465 square meters) of exhibit space, and a portable Starlab planetarium highlight the BCC's public outreach program.

The planetarium can seat 210 guests under a 70-foot (21m) projection dome. Shows run Wednesdays, Thursdays, and Fridays. Programs range from introductory tours of the night sky to laser-show extravaganzas.

The BCC Observatory houses a 24-inch Ritchey-Chrétien reflector. The dome is open Friday and Saturday evenings for public observing. Another smaller observatory contains a 12-inch telescope.

This facility's diverse mix of astronomical delights makes it a center of learning

Laura Layton is an associate editor of *Astronomy magazine*.

CONTACT INFORMATION

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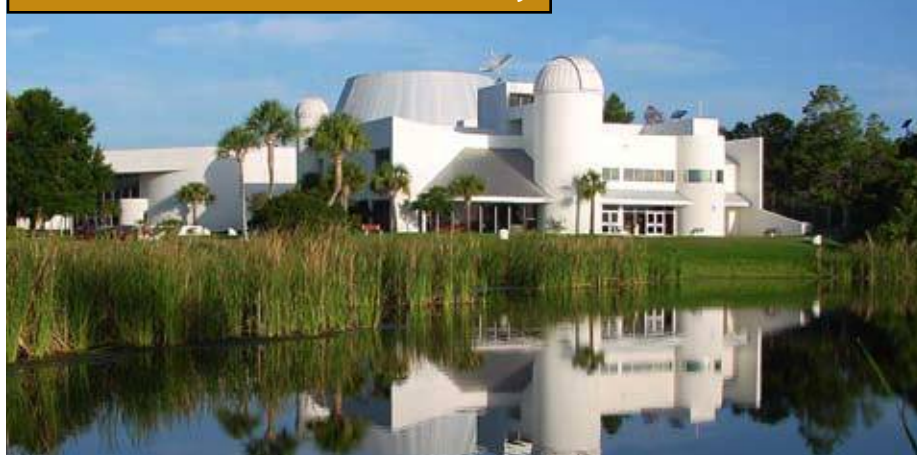
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BCC Planetarium and Observatory



TWO OBSERVATORIES and a planetarium theater make the 5,000-square-foot (465 square meters) BCC Planetarium and Observatory a popular destination for observers who live near Cocoa, Florida. CHUCK GREENWOOD

worthy of several visits to fully explore all it has to offer.

Eagle Eye Observatory

The Eagle Eye Observatory lies nestled in a dark-sky location on the Canyon of the Eagles Lodge and Nature Park, near Burnet, Texas. There, a sliding-roof observatory houses the Austin Astronomical Society's 16-inch Ealing Educator Telescope, a

Cassegrain instrument, a 12½-inch Newtonian Harlan Smith Telescope, and a 4-inch solar coronagraph.

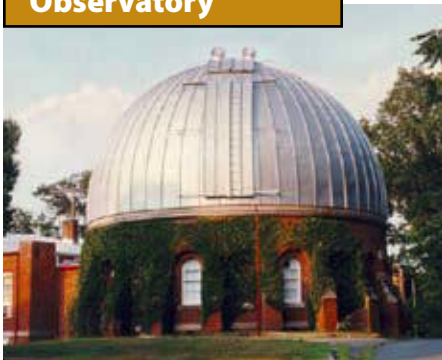
The Austin Astronomical Society (AAS) offers activities at Eagle Eye Observatory. Members host a variety of educational, public events. The observatory opens three nights a week, year-round, for public viewing. The AAS hosts monthly star parties and the annual CenTex Astronomy Weekend.

Eagle Eye Observatory



A DARK-SKY location makes Eagle Eye Observatory a good place for local observers to practice their hobby. Eagle Eye is situated inside the Canyon of the Eagles Lodge and Nature Park, about 15 miles northwest of Burnet. AUSTIN ASTRONOMICAL SOCIETY

Leander McCormick Observatory



OLD AND NEW come together in the form of a 26-inch Alvan Clark refractor and a 10-inch Meade SCT at the historic Leander McCormick Observatory in Charlottesville, Virginia, on the University of Virginia campus. UNIV. OF VIRGINIA

The AAS also hosts stargazing and moonlighting tours at Wild Basin Wilderness Preserve.

Leander McCormick Observatory

Third American President Thomas Jefferson (1743–1826) envisioned an observatory such as this when he established the University of Virginia in 1810. Leander J. McCormick (1819–1900) — a Virginia

The William Miller Sperry Observatory



AN OPTICAL SHOP and machine shop on-site help Amateur Astronomers, Inc., (AAI) astronomy club members maintain the William Miller Sperry Observatory. Located in Cranford, New Jersey, Sperry Observatory boasts two of the largest domes on the East Coast for use by amateur astronomers: the 18-foot (5.5m) East Dome houses a 10-inch f/15 refractor, and the 20-foot (6.1m) West Dome holds a 24-inch f/11 Cassegrain reflector. HANK ADAMS

farmer, manufacturer, and, later, wealthy Chicago businessman — built upon Jefferson's vision when he donated funds to the university for a 26-inch Alvan Clark refractor in the late 1800s.

Leander McCormick Observatory in Charlottesville, Virginia, opened to the public in 1885. In addition to its historic refractor, the observatory operates a modern 10-inch Meade LX-200 Schmidt-Cassegrain telescope and a 6-inch Alvan Clark refractor.

Run by the University of Virginia, this observatory serves the needs of university students and the public through a range of educational and outreach programs.

Weather permitting, the observatory opens for public observing the first and third Fridays of each month, excluding holidays. Educational groups can reserve observatory time the second and fourth Fridays of each month. Adult enrichment classes are available to community members by reservation Tuesday evenings. Classes include lectures, demonstrations, and hands-on activities with the historic 26-inch refractor.

The William Miller Sperry Observatory

Amateur Astronomers, Inc. (AAI), a non-profit organization founded in 1949, operates the William Miller Sperry Observatory at Union County College in Cranford, New Jersey. The group's mission is to promote the science of astronomy through courses, lectures, and hands-on observing sessions.

Sperry Observatory opened in 1967 with a \$150,000 endowment honoring local philanthropist and amateur astronomer William Miller Sperry. The observatory boasts a 24-inch f/11 Cassegrain reflector and a 10-inch f/15 refractor. Not only do AAI members operate two of the largest scopes for amateur use on the East Coast, but the group also maintains an optical shop, machine shop, library, classroom, and computer room. With all of these services available to AAI members, it's easy to see why this popular group has grown to more than 300 members.

Public programs at Sperry Observatory include slide presentations for kids, offered October through June, and a year-round schedule of talks most Friday evenings geared toward the general public. The youth program covers a variety of introductory topics, including solar system objects and the constellations. The general public program focuses on more advanced subjects like CCD image processing, understanding the Hubble galaxy classification scheme using Sloan Digital Sky Survey data, and how to choose a telescope.

Explore your community

To find an observatory in your area, contact your local astronomical society, community college, or university. You may be delighted by what you find and how an observatory can help you get to the next level of astronomy. ■

**ONLINE
EXTRA**

Visit www.astronomy.com/toc for program listings.

Sperry Observatory



KIM SCHOENHOLTZ, an AAI officer, stands at the controls of the 10-inch f/15 refractor in Sperry Observatory's East Dome. AMATEUR ASTRONOMERS, INC.

ASTRONOMY ON FILM

Timothy Ferris takes on his greatest challenge in filmmaking: recreating the sights, sounds, and emotions of stargazing. /// BY DANIEL PENDICK

Seeing in the Dark

Author and filmmaker Timothy Ferris' new documentary, *Seeing in the Dark*, asks stargazers what motivates them to go outside night after night and stare the cosmos in the face. The reasons are difficult to express. ❧ "In the course of writing a book and making a film about

amateur astronomy, I asked a lot of people what is it they find so compelling about stargazing, and no one has really been able to encapsulate the appeal of the night sky in words," Ferris explains. "It's rather like discussing why you love your spouse. The more you try to say about it, the more the inadequacy of the words becomes evident. But I find the ineffable nature of the subject appealing. It answers rather well to the silence of the night sky itself, and forms an appropriate axis for the film."

Shot to feature-film standards in high-definition (HD) video, *Seeing in the Dark* is Ferris' third film, joining *The Creation of the Universe* (1985) and *Life Beyond Earth*

(1999). The book version of *Seeing in the Dark* was published in 2002.

Ferris' latest film may be his most challenging to date — and his most personal. *Seeing in the Dark* is about his own lifelong love of the stars as well as amateur stargazers and the contributions they make to the study and appreciation of the cosmos.

Show and tell

Ferris looked at Mars through his first telescope in October 1956 — exactly 50 years, he points out, to the day before he began filming *Seeing in the Dark*. The film includes a flashback to those days, when he was 12 years old, as well as a second



PATRICK, Timothy Ferris' college-age son, played him as a teenager in Key Biscayne, Florida, exploring the night sky on the beach with his friends. FRANCIS KENNY

sequence set in Key Biscayne, Florida, with Ferris' son, Patrick, playing him at 17.

The flashbacks exemplify Ferris' approach: to show, not merely to tell. "The aim of a film like this is not to instruct people on how to find their way around the night sky, but to get them excited enough to want to try stargazing for themselves," Ferris says. "We do that in part by putting them directly in touch with the wonders of stargazing, and introducing them to accomplished amateur astronomers."

Among the amateurs featured in the film are *Astronomy* Contributing Editor Stephen James O'Meara and Robert Smith, a former running back for the Minnesota Vikings. "Looking through a telescope opens up this entire new world, or worlds," Smith tells Ferris on camera. "There's always this 'Wow!' factor. You know, 'I can't believe I'm actually seeing this.'"

Team Ferris

Ferris' million-dollar production enlisted a raft of filmmaking veterans, including feature-film cinematographer Francis



TIMOTHY FERRIS edits a special-effects scene in which the viewer travels seamlessly from video of the constellation Orion rising over a California vineyard, to a stunning color astro-photo of Orion's center, to a special-effects journey into the Orion Nebula. CAL ZECCA

Daniel Pendick is an associate editor of *Astronomy*.



ROBERT SMITH (above looking through the telescope), an amateur astronomer and former star running back for the Minnesota Vikings, shows the sky to Miami teens. MARK DIAMOND



MARK DIAMOND

Kenny (*Scary Movie*), sound designer Kate Hopkins (*Planet Earth*), sound mixer Walter Murch (*Apocalypse Now*), and veteran astronomical artist Don Davis (*Cosmos*). Mark Knopfler and Guy Fletcher, of Dire Straits fame, produced the original music.

"The night sky is a magnificent subject," Ferris says, "and I made a wish list of top creative people to help me capture it on the screen. I'm happy to say that nobody turned us down."

Simulated stargazing

No motion-picture camera can yet come close to the night-vision sensitivity of the human eye, Ferris says, but he and Kenny were able to come close. They shot scenes with cinema-quality Zeiss lenses and top-notch HD cameras, while judiciously using small LED panels to light nighttime scenes. Each of the 30 frames the HD camera shoots per second contains up to 10 megabytes of data, or enough to overflow a standard CD-R disk for every minute of film.

For a scene of the teenager Tim Ferris stargazing with friends on a Florida beach, Ferris needed a deep, twinkling night sky. To simulate what the naked eye captures

when we simply look up at night, Ferris started with wide-field photographs of the night sky by astro-photographer Akira Fujii. Space artist Don Davis then animated the still image to add a naturalistic twinkling.

To create the twinkling effect, Davis shot video footage of Sirius — the bright main star in Canis Major the Big Dog — slightly out of focus and on a night when the air was unsteady. This yielded what Davis describes as "a shimmering little disk that fluctuated greatly in brightness." Davis digitally pasted the disk on top of every bright star in Fujii's photos.

Three weeks of work gave Ferris his twinkling night sky, which he then placed digitally into the live-action scene of his younger self looking up at the sky. Davis also produced more conventional special-effects sequences for the film, including a close-up peek at Saturn's ring spokes, a journey into the Orion Nebula, and a fly-over of the Andromeda Galaxy.

Through the lens

To recreate through-the-eyepiece views, Ferris used HD cameras to shoot bright objects such as Jupiter and Saturn through telescopes. In a scene when the legendarily sharp-eyed O'Meara recounts his early experiences observing Saturn and seeing the ring spokes, the viewer sees something like what O'Meara saw: a glowing Saturn in sharp clarity for a tantalizing moment, then drifting back out of focus.

For dimmer objects, Ferris started with stills or time-lapse footage and then added

A BRIEF HISTORY OF TIMOTHY FERRIS

- 1944** Born August 29 in Miami.
- 1956** Acquires first telescope, observes opposition of Mars.
- 1977** First book, *The Red Limit*, published. Produces phonograph record launched into space aboard Voyager space probes.
- 1985** Writes and narrates his first PBS special, *The Creation of the Universe*.
- 1986** Awarded Guggenheim Fellowship.
- 1988** Publishes book, *Coming of Age in the Milky Way*, which is nominated for Pulitzer Prize.
- 1992** Publishes book, *The Mind's Sky*.
- 1997** Publishes book, *The Whole Shebang*.
- 1999** Writes and narrates his second PBS special, *Life Beyond Earth*.
- 2002** Publishes 11th book, *Seeing in the Dark*; book awarded PEN Center USA Literary Award.
- 2003** Publishes 200th article.
- 2007** Finishes his third PBS special, *Seeing in the Dark*.

atmospheric distortions created digitally. "Reverse-engineering the scintillations of, say, the Beehive Cluster as seen through an 18-inch telescope at 75x, is essentially a matter of stacking several layers of random numbers that match prevalent patterns of atmospheric turbulence," Ferris says.

Ferris shot and processed some of the film's astronomical time-lapse footage and recorded hours of ambient night sounds on a digital recorder with no moving parts that he says was able to capture the "subtle, low-level night sound" surrounding observers in remote outdoor settings.

The result is a thoughtful recreation of stargazing — but, of course, not as rich as the real thing. So, watch Ferris' film. But don't forget to look up afterward. ■

/// WHEN TO WATCH

Seeing in the Dark will premiere on the Public Broadcasting System September 19 at 8 P.M. Eastern Standard Time. Check your area's public television listings for local air times. A companion web site will be live when the film airs: www.pbs.org/seeinginthedark.

ONLINE EXTRA

To see a sneak preview of *Seeing in the Dark*, go to www.astronomy.com/toc.

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Astro-Tech's new 111mm ED triplet apo is only \$1895.

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nences exploding while you watch.

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pieces. At only \$69.95, it is certainly a best buy and one of five great-value dielectric diagonals from Astro-Tech.



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The hot Celestron SkyScout. In stock now.

Last fall, it was almost impossible to find the **Celestron SkyScout**. This *Sky & Tel Hot Product* for 2007 is still selling like there's no tomorrow, but we have a SkyScout in stock for you today.

This GPS-based non-magnifying hand-held personal planetarium locates and

identifies over 6,000 celestial objects visible to your unaided eye. Earbuds tell you their stories, or you can read them on a scrolling 5-line text and graphics display.

The optional \$124.95 **Orion SkyLine laser pointer** mounts on the SkyScout to point a green line at sky objects as you identify them. SkyScout makes the night sky as familiar as your own back yard.

GPS tells a Meade LX90 where it is . . . so you don't have to!

Meade LX90 8", 10", and 12" go-to Schmidt-Cassegrain telescopes use a GPS (Global Positioning System) that makes it easy for you to find your way to any object in the night sky. The high light transmission of their UHTC multicoated optics makes sure you see everything there is to see once you get there.

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Simply check that your LX90's finder scope (it has two, an 8 x 50mm and a red dot) is centered on those stars, then start enjoying the best in 21st century computerized go-to observing at the touch of a button. A Meade LX90 makes astronomy pushbutton easy.

Here are the prices on the Meade LX90 scopes that we stock:

8" LX90-GPS, with UHTC optics \$1999
10" LX90-GPS, with UHTC optics 2699
12" LX90-GPS, with UHTC optics 3299



Meade 8" LX90-GPS \$1999

TMB triplet apo refractors start under \$1000!

The **TMB Optical TMB-80** 80mm f/6.3 triplet apo refractor is only \$995. It's the first time a genuine TMB Optical refractor has been available at such an attractive price. Like all TMB refractors, it uses premium FPL-53 ED glass in a fully multicoated apochromatic (color-free) triplet lens. The TMB-80 has a rotating 2" Crayford focuser; 1.25" and 2" compression ring eyepiece holders; and more. A true TMB apo for under \$1000? Wow!

The 130mm f/7 **TMB-130** apochromatic triplet, left, is a *Sky & Telescope Hot Product* for 2007. Unlike other premium refractors that have multiyear waiting lists, this outstanding \$3999 apochromatic refractor from renowned optics designer Thomas M. Back is available now.

The very compact 92mm f/5.5 **TMB-92** triplet apo to the right fills the void left by the discontinued 90mm Astro-Physics Stowaway (a legendary scope that sells for up to \$6000 on the used market). But you won't pay \$6000 for the TMB-92. This fast focal ratio 92mm TMB apo is only \$1999.

The TMB-130 and TMB-92 both have collimatable lens cells and each features a famous *FeatherTouch* dual-speed rotating rack and pinion focuser (a 3.5" drawtube model on the TMB-130, and a 2.7" on the TMB-92).



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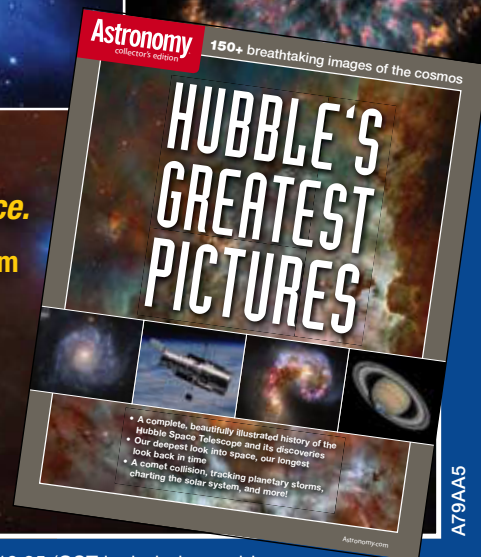
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TELESCOPE REVIEW

The LXD75 AR-6 AT achromat delivers high-quality performance.

/// BY TOM TRUSOCK

Meade's affordable large refractor

When artists want an image to scream “telescope,” all they need to do is draw a sleek tube, put it atop a tripod, and point it at the heavens. Refractors embody the idea of the telescope. And for observers, what’s not to like? Besides the fact that refractors are sleek and compact,

they offer crisp images and fewer collimation troubles compared to large reflectors.

If you yearn for a large-aperture refractor without having to take out a second mortgage, consider Meade’s LXD75-series AR-6 AT achromatic telescope. Like any achromatic refractor, the AR-6 AT’s objective lens — a 6-inch f/8 achromatic doublet — does not correct color distortions as well as pricier apochromatic telescopes. However, this scope, along with its popular LXD75-series equatorial mount, delivers solid performance at a price that won’t bust your equipment budget.

Commanding presence

The AR-6 AT’s optical tube and mount arrive in separate boxes. Included, you’ll find the LXD75-series mount and tripod, the tube cradle and rings, two 10-pound counterweights, an 8x50mm finder, a 26mm Plössl eyepiece, a 1¼" star diagonal, a battery pack for 8 D-cell batteries, an Autostar controller, all needed cords and cables, and documentation. The mount’s spreader bar features holes for three 1¼" eyepieces. Unpacking and assembling the equipment takes approximately 20 minutes.

The telescope’s sheer size gives it a commanding presence. Its multicoated objective lens sits in a mount whose adjusters are

easy to reach when collimating. As you would expect with a refractor, the lens was already well collimated.

The focuser is a lockable 2" rack-and-pinion movement with 4⁵/₈" of focus travel and 1½"-diameter focus knobs. A locking metal collar rotates the diagonal. Dual set-screws hold accessories in place. The focuser, although lubricated with thick grease, moved freely even in sub-zero temperatures and had a smooth but firm feel. The dew shield is removable, but not retractable. I found the shield, extending only 4" from the lens, too short to be truly effective on humid nights.

The tube measures 8" by 51" (20 by 130 centimeters) and weighs 27 pounds (12 kilograms) with the rings, finder, and diagonal attached. The mount and counterweights add 65 pounds (29 kg), raising the total system weight to 92 pounds (42 kg).

A LARGER APERTURE delivers noticeably greater light-gathering power. The refractor’s 6-inch objective lens gathers 9 times more light than a comparable 2-inch refractor and 4 times the light of a 3-inch refractor. ASTRONOMY: JAMES FORBES

I could carry both the telescope and mount, but most users will probably transport the telescope and mount separately.

Acceptable correction

I found the optics to be slightly under-corrected but detected no evidence of astigmatism or other aberrations. As you would expect with an achromatic refractor — whose objective lens only partially corrects for chromatic aberration — color fringes appeared around bright objects.

For example, when observing Vega, I saw purple and green fringes. However, I found the fringing surprisingly unobtrusive for most objects. Lunar shadows showed a fair amount of purple, but with a lot of detail still present, even up to 300x.

In addition, I easily split the Double Double in Lyra at 95x and came close to a



THE MEADE LXD75 AR-6 AT achromatic refractor system combines ample light-gathering power and accurate, reliable go-to performance from its German equatorial mount. PHOTO: JAMES FORBES; STAR ATLAS BACK-

GROUND: ASTRONOMY; ROEN KELLY AND RICHARD TALCOTT



clean divide at 72x. A split of double stars at low power indicates high-quality optics.

One after another, globular clusters, double stars, nebulae, and galaxies fell prey to the big refractor. I often observe with a 4-inch telescope, and I had forgotten what a difference just 2 more inches can make. The Hercules Cluster (M13) revealed dozens of pinpoint stars swarming across an unresolved glow. A partially resolved M15, a globular cluster in Pegasus, put on an excellent show, and the Ring Nebula (M57) was an ethereal oval floating at the bottom of a deep, dark well. With a 2" diagonal and wide-field eyepiece, the Merope Nebula (NGC 1435) in the Pleiades was

simply jaw-dropping, and I had no trouble spotting it. The Dumbbell Nebula (M27) lay bare its distinctively shaped apple core.

With the tripod legs fully extended and the scope pointed at the zenith, the eyepiece stood a mere 29 inches (74 cm) off the ground, a convenient height for seated observing. I could easily view in any direction, and the scope never hit the tripod.

The LXD-series mount

As with any telescope system, the optics are only half the story. The mount can make or break a system, so I'm happy to report the equatorial performed like a champ. It

/// SPECIFICATIONS

MEADE LXD75 AR-6 AT

Type: Achromatic refractor

Aperture: 6 inches (152 millimeters)

Focal length: 1,219mm

Focal ratio: f/8

Tube length: 51 inches (130 cm)

Assembled weight: 92 pounds (42 kg)

Included: 26mm Plössl eyepiece (47x), 8x50mm finder, 1¼" star diagonal, battery pack for 8 D-cell batteries, Autostar controller

Mount: Computer-controlled Meade LXD75 equatorial mount with full go-to control

Database: 30,223 objects

Price: \$1,199

Contact information

Meade Instruments Corporation
6001 Oak Canyon
Irvine, CA 92618
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[w] www.meade.com

tracked well for visual use. With only a rough polar alignment and using moderate eyepiece powers, the drive kept objects in the field for 15 to 20 minutes. The AutoStar's go-to function placed more than 95 percent of the targets in a 2" low-power eyepiece, and kept objects in the included 26mm Plössl around 85 percent of the time.

Because of the optical tube's length, it took slightly longer to damp down vibrations than I prefer. But overall, the mount performed quite well, and I consider it a major strength of the system. Also, because the mount uses a standard dovetail, you can quickly and easily connect several different telescopes. Compatibility with many other telescopes is a feature potential purchasers should value highly.

Big-aperture bargain

The LXD75 AR-6 AT system provides lots of light-gathering bang for your buck and also delivers a good out-of-the-box experience, especially when you consider how much a 6-inch refractor would have cost just a few years ago. If you're on a budget but dreaming of owning a big refractor, consider Meade's offering. It might just make those dreams come true. ■

{ NEW PRODUCTS }

ATIK ATK-16IC CCD CAMERA

Adirondack Video Astronomy
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The Atik ATK-16IC monochrome CCD imaging system is equipped with a 7.4-micron Sony image sensor and a thermoelectric cooling system. The camera comes with a 1¼" adapter, USB cable, software, and a user's manual.

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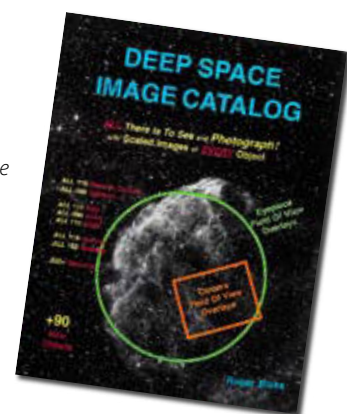


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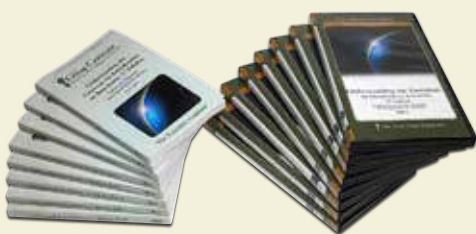


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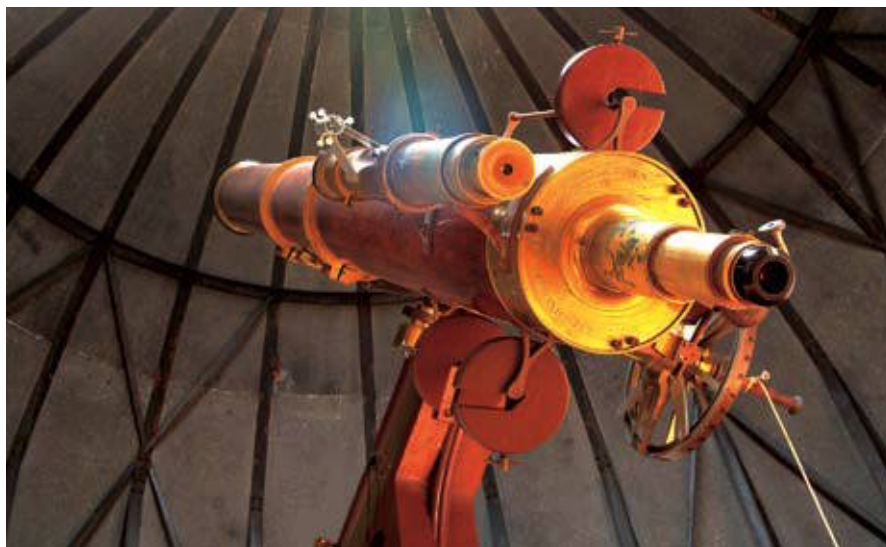
{ COMING EVENTS }

SEPTEMBER 2007

SEPTEMBER 22

Walk through astronomy's history

ScopeOut is a daylong event held at the historic Cincinnati Observatory. If you are interested in antique equipment, the observatory displays restored Riefler pendulum clocks, an 1843 Merz and Mahler refractor, and a 1904 Alvan Clark refractor. ☾ Activities will



SCOPEOUT will give visitors the rare chance to observe through an 1843 Merz and Mahler refractor — the oldest scope still used at a North American observatory. MARY STRUBBE

include solar observing, telescope-making demonstrations, lectures, and a children's astronomy art exhibition and contest.

The keynote speaker will be Steele Hill, the media specialist for NASA's SOHO, TRACE, and STEREO missions.

☒ observatory@fuse.net; ☒ www.cincinnatiobservatory.org/scopeout.

SEPTEMBER 5-7

Astronomical Society of the Pacific's EPO Conference and Annual Meeting

Holiday Inn Chicago Mart Plaza, Chicago. ☒ www.astrosociety.org/events/meeting.html.

SEPTEMBER 6-9

Astrofest

Vana's Farm, Kankakee, Illinois.

☒ chicagoastro.org/af/index.html.

SEPTEMBER 6-9

Huron Star Party

Camp Saulaine, near Ivy, Ontario.

☒ gordrife@sympatico.ca; ☒ www.cois.on.ca/~ssaa.

SEPTEMBER 6-9

Iowa Star Party

Whiterock Resort, Coon Rapids, Iowa.

☒ Liz Garst at 712.684.2964; ☒ www.farmresort.com/iowastarparty.htm.

SEPTEMBER 7-9

Sierra Summer Star Party

Alpine County Airport, Eastern High
Sierra, California. www.sierrastar.org.

SEPTEMBER 7-9

South Dakota Star Party

Hodgson Observatory, Beresford, South
Dakota. starparty@inskysd.org;
www.sdsp.org.

SEPTEMBER 11-16

Northern Prairie Starfest

Black Nugget Lake, near Tofield, Alberta.
www.edmontonrasc.com/nps.html.

SEPTEMBER 13-16

Great Lakes Star Gaze

River Valley RV Park, Gladwin, Michigan.
www.boonhill.net/sunset/sasglsg.htm.

SEPTEMBER 13-16

Prairie Skies Star Party

Camp Shaw-Waw-Nas-See, near Bourbon-
nais, Illinois. www.prairieskies.org.

SEPTEMBER 14-15

Cathedral Gorge Star Party and Campout

Cathedral Gorge State Park, near Panaca,
Nevada. geary.keilman@lvastronomy.com;
www.lvastronomy.com.

SEPTEMBER 14-16

ASNNE Starfest

Starfield Observatory, Kennebunk, Maine.
www.asnne.org.

SEPTEMBER 15-16

Web Cam Workshop

Kitt Peak National Observatory, Tohono
O'odham Reservation, Arizona. ☎ 520.
318.8726; rwilson@noao.edu; www.noao.edu/outreach/kpvc/imaging.html.

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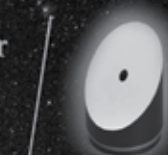
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Reader gallery



DEEP-SKY TREASURE HUNT

The Cone and its neighbors

Several colorful deep-sky objects lie in Monoceros the Unicorn. Star-forming region NGC 2264 is a “combination” object — it contains both the dark nebula known as the Cone Nebula and the open star cluster dubbed the Christmas Tree Cluster. The 7-light-year-long Cone points toward bright, blue-white S Monocerotis, a quadruple system of hot stars. The yellowish star cluster Trumpler 5 sits below center. Blue reflection nebula IC 2169 scatters nearby starlight. At bottom left, Hubble’s Variable Nebula (NGC 2261) shines as a tiny V-shaped object. This image measures 2.5° wide.

THE CONE NEBULA (NGC 2264) REGION

(5-inch Tele Vue 127is apochromatic refractor at f/5.2, Apogee U9000 CCD camera, H α RGB image with exposures of 9.25, 7.3, 7.3, and 7.3 hours, respectively) /// **ADAM BLOCK AND TIM PUCKETT, ELLIJAY, ARIZONA**



NGC 3169 AND NGC 3166 form a pair of 10th-magnitude spiral galaxies in Sextans. Less than 8' separate the objects, which lie 8.6° south of Regulus (Alpha [α] Leonis). (20-inch RC Optical Systems

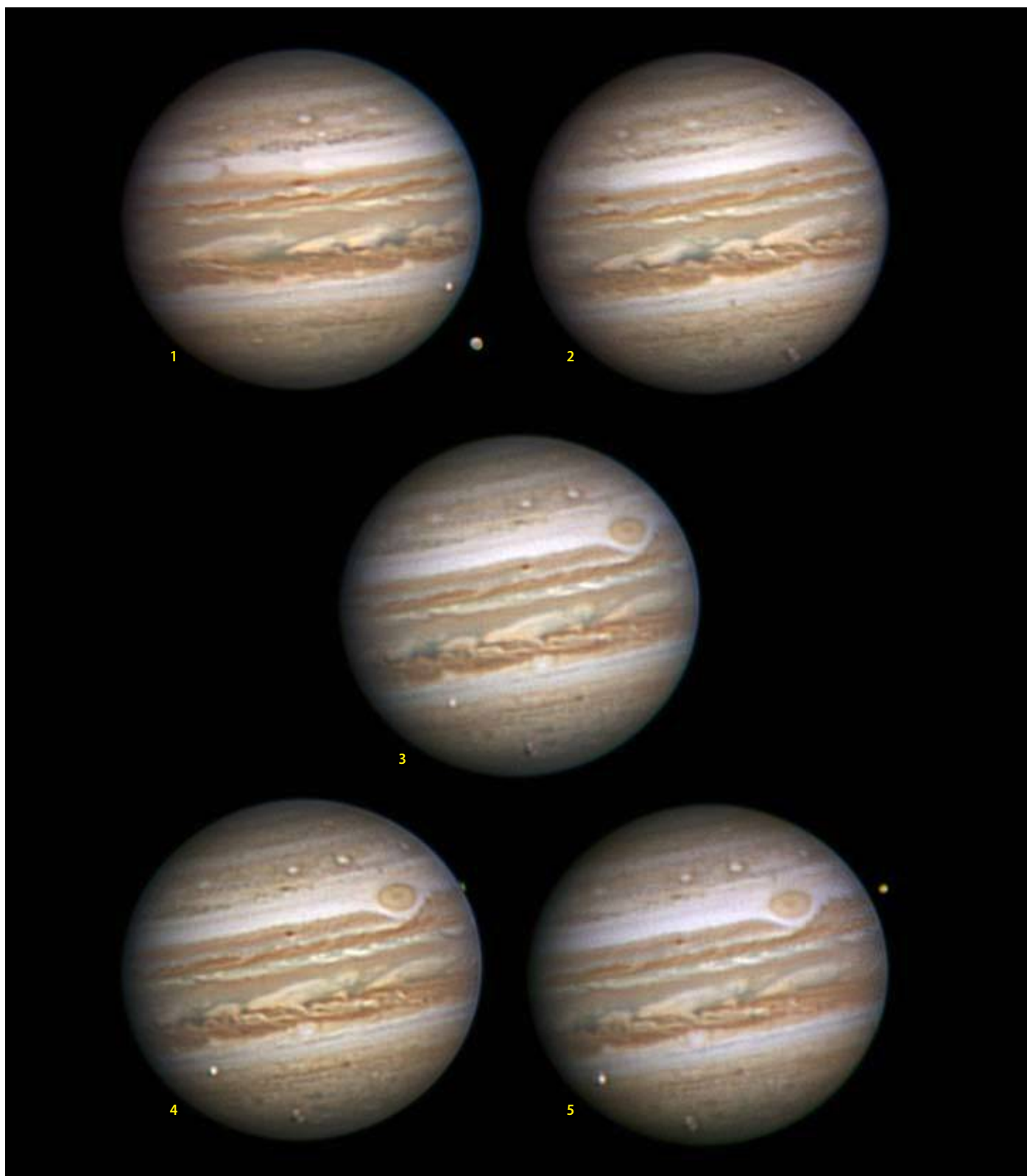
Ritchey-Chrétien telescope at f/8.3, Yankee Robotics Trifid II 6303E CCD camera, LRGB image with exposures of 255, 135, 135, and 180 minutes, respectively) /// **KEN CRAWFORD, CAMINO, CALIFORNIA**



OPEN CLUSTER M35 in Gemini travels across the sky with a smaller, fainter companion cluster, NGC 2158. M35 shines at magnitude 5.1, making it a naked-eye sight from a dark location. (4-inch Tele Vue

NP-101 apochromatic refractor at f/5.4, SBIG ST-2000XM CCD camera, LRGB image with exposures of 108, 90, 45, and 45 minutes, respectively) /// **BERNHARD HUBL, NUSSBACH, AUSTRIA**

Send your images to: *ASTRONOMY* Reader gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of image and complete photo data: telescope, camera, and exposure information. To submit images electronically, visit www.contribute.kalmbach.com.



THIS JUPITER SEQUENCE shows the planet's rotation during a span of 2 hours 10 minutes. (12-inch GSO Newtonian reflector at f/5, DMK21AF04 CCD camera, LRGB image with $\frac{1}{30}$ -second unfiltered

luminance exposure and $\frac{1}{15}$ -second exposures through red, green, and blue filters, taken March 22, 2007, from 16h30m to 18h40m UT) /// **MIKE SALWAY, ERICSSON, AUSTRALIA**



THE VOLCANO NEBULA is part of the Milky Way's integrated flux nebulosity (IFN), which is mainly galactic dust above and below our galaxy's plane. This nebulosity is not illuminated by a single star or star cluster, but by the integrated brightness of all nearby stars. (6.4-inch Takahashi Epsilon 160 at f/3.3, SBIG STL-6303 CCD camera, LRGB image with exposures of 3, 1, 1, and 1 hours, respectively) /// **DEAN SALMAN, TUCSON, ARIZONA**





ONE PICTURE IS WORTH A THOUSAND WORDS



This beautiful two frame mosaic image of M42 and NGC1977 was taken with an SBIG self-guiding ST-2000XCM single-shot color camera by Ed Henry through an 80mm f/6 refractor

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2008 *Astronomy's*
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Choosing the best telescope for yourself or someone else requires the right information.

/// BY TOM TRUSOCK

A supplement to
Astronomy magazine.

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Whether you're an advanced amateur astronomer or a novice purchasing a telescope as a gift, you face a bewildering array of choices. Many factors go into deciding which scope to buy, but the first step is to get a handle on what's out there.

Some observers favor the light-collecting power of reflectors. Others appreciate a refractor's simplicity, classic lines, and ease of use. Some want the flexibility a compound telescope can deliver. In this guide, I've included something for everyone. Remember, some of these telescopes require you to provide a mount — be sure to check the charts (pages VIII, XVII, and XX) for details.

Observers' requirements differ, so I've included telescopes that range in cost from under \$200 to nearly \$10,000. And while it's true that the best views typically come from premium optics, I've also enjoyed observing with many of the less expensive scopes.

I don't have the space to list every telescope on the market, but you'll find a good selection from many manufacturers. I've grouped the telescopes according to type.

As any experienced amateur will tell you, personal preference counts for a lot when choosing a telescope. If you're considering buying, you should get out to a star party. Nothing takes the place of getting "hands-on" experience with a scope to determine if you and it have a future together.

Check out "Coming events" in the latest issue of *Astronomy* or on Astronomy.com for more information on events near you.

Refractors

A refracting telescope uses lenses to focus light. High-quality refractors provide crisp, high-contrast images with low maintenance. You won't have to collimate (align the telescope's optics) or recoat the optical surfaces.

People who travel frequently or who have little storage space may prefer a small refractor, which are perfect for grab-and-go observing. Refractors are also excellent photographic platforms. And, finally, they have those classic lines that simply scream "telescope." The best telescope is the one you use the most, and, for many, a small refractor fits the bill.

Tom Trusock is a prolific telescope reviewer who observes from rural Michigan.

Refractors come in two types: achromatic and apochromatic, based on the lens' degree of color correction. An uncorrected lens suffers from a defect called chromatic aberration. This defect occurs when light of different colors lies at different focus points. Achromatic refractors bring two colors (usually red and blue) to a common focus, providing a good degree of color correction.

Apochromatic refractors bring three colors to a common focus. So, apochromats show less chromatic aberration than achromatic refractors of similar aperture and focal length. The improved correction, which involves more lens elements and better glass, carries a higher price. Because apochromats cost more, achromatic refractors, especially large ones, still have quite a following.

A&M Telescopes 1056W

A&M offers something exotic for the advanced amateur. Take top-notch Russian optics, couple them with a state-of-the-art focuser, a carbon-fiber OTA, and an Italian sense of design, and you're beginning to get the picture.

The 1056W uses an apochromatic triplet lens with a center element of OK-4 glass, which resists temperature-induced aberrations, to provide excellent color correction. It's capable of wide fields of view and razor-sharp high magnifications.

The 4" focuser can handle nearly any size camera and fits the scope well. The 1056W is short, around 21 inches, which makes it a perfect travel scope. This scope is an astrophotographer's dream — and it's one visual observers will enjoy as well.



Astronomy Technologies AT66ED

While I'd normally have reservations about recommending a scope with less than 3 inches of aperture, every once in a while there comes a product everyone should own. This apochromatic doublet is just such a beast.

First off, it's tiny — with the dew shield retracted, it's just under a foot (305mm) long and weighs less than 4 pounds (1.8 kg). Its 1.6" visual back has SCT threads that allow you to attach a range of accessories easily. The short focal length makes it a wonderful tool for scanning the Milky Way, and its small aperture and FPL-51 glass let you crank up the magnification on the Moon without false color becoming too intrusive.

The AT66ED can serve as a great grab-and-go scope, a fine little astrograph, a super-finder scope, and a daytime spotting scope. At \$329, it's a good value. The only real question is which of the 7 available colors do you want?





Meade 80 ED APO

Meade's re-entry into the apochromatic refractor market is something that many have anticipated. It comes in the form of the inexpensive 3.2-inch f/6 Series 5000 ED APO refractor. (The "ED" often attached to refractor names refers to the type of glass used in the lens — extra-low dispersion.)

Meade's package touts an optical-tube assembly with a Crayford-style focuser, sliding dew shield, and mounting bracket. Further, Meade includes an aluminum-frame carrying case. This new ED triplet provides good color correction and, for the price, a lot of bang for the buck.

Celestron Omni XLT 102

If you're willing to do without a go-to drive, a good choice for astronomy newcomers is Celestron's Omni XLT 102. This 4-inch f/9.8 achromatic refractor sits on the company's tried-and-true CG-4 equatorial mount.

A 4-inch scope not only performs well on bright targets, but it also pulls in a surprising number of deep-sky objects. The maximum true field of view measures $1\frac{1}{4}^\circ$, or two and a half Full Moon diameters.

I recommend the optional Celestron motor drive and a good red-dot finder as upgrades. At 43 pounds (19.5 kg), the setup is fairly beefy, but most users will be able to carry it out in a single trip — perfect for impromptu sessions.



Burgess Planet Hunter 80

When I was a child, all amateur astronomers had long-focal-length refractors, and all the telescopes were white. Burgess' Planet Hunter 80 takes me back to those roots.

This lightweight, TMB-designed, 3.2-inch f/11.25 achromat is a bit of a throwback — but in a good way. Its slow focal ratio means you can achieve higher magnification with shorter-focal-length eyepieces. Also, a long focal ratio means less excess color.

Both of these traits serve the lunar, planetary, and double-star observer well. The Planet Hunter features a dual-speed, Crayford-style focuser and Burgess' Multi-reticle Reflex finder. Best of all, with those long classic lines, this telescope just looks cool.





Celestron NexStar 80 SLT

Here's another inexpensive choice for a beginner looking for a small refractor, and this one comes with a go-to mount. The NexStar 80 SLT employs a 3.2-inch f/11.25 achromatic doublet that gives nice views of the Moon, planets, and double stars without breaking the bank.

The nice part about the NexStar 80 SLT's setup is the included mount. It provides tracking and, with a 4,000-object database, even helps the beginner find targets. The setup's no-tool assembly makes taking it to dark sites a snap.

Meade LXD75 AR-6 AT

On the other end of the size spectrum for refractors, we find the Meade 6-inch f/8 LXD75 AR-6 AT. This package includes a 6-inch f/8 achromatic doublet refractor mounted on the LXD75 go-to mount.

Just add batteries, and you can observe with this setup right out of the box. The AR-6 units I've used have done a first-rate job on deep-sky objects and also do quite well for casual lunar and planetary looks.

Beware of its size, though — on the LXD75 mount, it's definitely "all that" and a bit more. Given the \$1,199 price tag for both scope and mount, it's a heck of a buy.



Orion ShortTube 80

For budget-minded consumers, Orion offers several choices in the small refractor market. One is Orion's inexpensive ShortTube 80, a 3.2-inch go-anywhere scope with decent light grasp. While it's been eclipsed by apochromatic refractors that have dominated the market for the last few years, this little achromat is still a solid performer for someone looking for low-power, wide-field views of the night sky. As a bonus, the ShortTube 80 is light-weight enough to be mounted as a super-finder on a larger scope, thus giving you the best of both worlds in one setup.



Orion 80ED

Also of note from Orion is the 80ED. This scope is the one that started today's small, cost-effective apochromatic-refractor trend. It uses a 3.2-inch, air-spaced f/7.5 doublet with a 2" Crayford-style focuser. Both the mechanics and the optics still get the job done, and rather well at that. I've owned two of these, and, optically, they've both delivered nearly textbook star images and excellent color correction. The dew shield does not retract but can be removed easily. The OTA is oversized, so the scope's a bit bigger than one might expect. Given the price, this scope is a wonderful value.



Tele Vue TV-60is

For amateur astronomers interested in both observing and photographing the night sky, Tele Vue introduced its "is" (Imaging Series) lineup. The TV-60is is another exception to my 3-inch rule. Quite possibly the ultimate ultra-wide-field astrograph, the 2.4-inch 60is sports a 2" focuser, the Focusmate, for 6-to-1 focus reduction, and a six-point mounting system. Optionally, you can equip this little scope with digital-micrometer-based focus measurement and a field flattener. I've seen many images taken with the 60is, and both the resolution and field size are impressive.



Pentax 100 SDUF II

Devoted astrophotographers now have another optical tool in their arsenal — the Pentax 100 SDUF II. This 8.8-pound (4 kg) 4-inch refractor measures less than 20 inches (508mm) when stowed, but it fills the fields of large-format (6" by 4.5") cameras.

Touting superb Pentax SMC multicoatings for maximum transmission, its lens has four elements in two groups. The 100 SDUF II gives observers wide, well-corrected fields of view. It sports a calibrated helical focuser, and comes with a case. It's tiny, gorgeous, and it can be yours for just under \$3,000.



Tele Vue NP-127is

Tele Vue's esteemed 5-inch NP-127 telescope comes in an "is" version as well. To better accommodate imagers, Tele Vue increased the size of the rear-element group in this series to nearly eliminate vignetting (cutting off or dimming an image's outer region) over a full CCD chip measuring 2 inches (50mm) diagonally.

These scopes further boast an enhanced focuser, which includes a camera tilt-plane adjustment, the Focusmate, Focusmate driver, and a digital micrometer to measure focuser position. This scope is well-equipped for today's imager.

Takahashi TSA-102S

The performance of Takahashi's FC and FS series is legendary among refractor lovers, but due to changes in fluorite-glass availability, Takahashi decided to redesign the lineup. It recently introduced the TSA-102S, a 4-inch apochromatic triplet.

The heir apparent to the Takahashi legend, the TSA takes no prisoners. With high-contrast, color-free images, and pinpoint stars, this is one scope determined to stand on its own merits. The TSA boasts a 2.7" focuser and measures a mere 23 inches (584mm) long with the dew shield collapsed. This f/8 scope also has focal reducers available that will take it down to f/5.98 for imaging, if your aspirations lie along photographic lines.

Tele Vue TV-85

If you're purely a visual observer, you may not want to pay for the imaging extras that come with Tele Vue's "is" line. Never fear, Tele Vue has some first-rate selections to address that dilemma.

If I had to pick just one scope out of the Tele Vue lineup for visual use, it would be the TV-85. This one is small enough to meet airline carry-on requirements, yet it still provides respectable light grasp. This f/7 apochromatic doublet will give a maximum true field of 4.4° for jaw-dropping views of the Milky Way.





StellarVue 90T

If you're an amateur astronomer looking for the ultimate portable instrument, StellarVue offers the 90T. Just under 20 inches (508mm) long with the dew shield retracted, this 3.6-inch triplet boasts superb optics (a fluorite triplet) and excellent correction across the field of view. A 2" Feathertouch focuser and the "binoviewer ready" option are good complements to the package. This f/7 refractor comes with an airline carry-on case and a reflex finder.

William Optics ZenithStar 80 II ED

William Optics is one of the "big bang for the buck" leaders in today's refractor market, and the ZenithStar 80 II ED is right on target. William Optics products are well-known for their mechanical quality, and this little scope is no exception.

It comes with a 2", 360° rotating, calibrated focuser; retractable dew shield; mounting bracket; and hard case. The heart of the scope is its fluorite-glass-based air-spaced doublet, which offers great views and good color-correction for a low price.

While the color-correction isn't quite as good as in some of William Optics' higher-quality glass doublets, the price is a couple of hundred dollars less. If you're a visual observer looking to see what the apochromatic buzz is all about, this scope comes highly recommended.





Vixen ED103SWT

Vixen has been something of an underdog in the North American market, and that's a pity considering the sheer value of its equipment. The Vixen ED103SWT f/7.7 doublet refractor may be just the ticket for first-timers seeking that 4-inch apochromatic experience.

Its light weight — under 8 pounds (3.6 kg) — makes it easy to transport and, most importantly, allows the use of small, lightweight mounts. The dew shield retracts for travel and storage. The scope comes with a 2" rack-and-pinion focuser (with 1¼" adapter), 1¼" flip-mirror diagonal, rings, and a 7x50 finder scope.



TMB 130SS

Many passionate amateurs spend their evenings dreaming of large apochromatic refractors. TMB's Signature Series lineup aims to fulfill those dreams. The first scope out of the gate is the 5.2-inch TMB 130SS.

An exceptional TMB design coupled with superb optics and first-rate mechanics, this scope is generating a lot of buzz among amateur astronomers. At its price, it's quite possibly one of the best deals on the market. Models initially shipped with a 4" dual-speed, rack-and-pinion focuser, but, after listening to user feedback, Thomas M. Back switched to that perennial favorite, the Feathertouch, and made a good telescope even better.

REFRACTOR COMPARISON

Manufacturer/Model	Aperture	f/ratio	Mount/tripod included?	Price
A&M Telescopes 1056W	4.1" (105mm)	6.2	No	\$3,407
Astronomy Technologies AT66ED	2.6" (66mm)	6.0	No	329
Burgess Planet Hunter 80	3.2" (80mm)	11.25	No	399
Celestron NexStar 80 SLT	3.2" (80mm)	11.25	Yes	379
Celestron Omni XLT 102	4.0" (102mm)	9.8	Yes	399
Meade 80 ED Apo	3.2" (80mm)	6.0	No	599
Meade LXD75 AR-6 AT	6.0" (152mm)	8.0	Yes	1,199
Orion ShortTube 80	3.2" (80mm)	5.0	No	189
Orion 80ED	3.2" (80mm)	7.5	No	499
Pentax 100 SDUF II	4.0" (100mm)	4.0	No	2,995
StellarVue 90T	3.6" (90mm)	7.0	No	1,995
Takahashi TSA-102S	4.0" (102mm)	8.0	No	2,695
Tele Vue TV-60is	2.4" (60mm)	6.0	No	1,695
Tele Vue NP-127is	5.0" (127mm)	5.2	No	6,985
Tele Vue TV-85	3.4" (85mm)	7.0	No	1,750
TMB 130SS	5.2" (130mm)	7.0	No	3,999
Vixen ED103SWT	4.0" (103mm)	7.7	No	1,999
William Optics ZenithStar 80 II ED	3.2" (80mm)	6.8	No	528

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Reflectors

The reflecting telescope uses mirrors ground to exact curves to bring light to a focus. Isaac Newton (1643–1727) invented the reflector, so you'll hear the original design, which incorporates a parabolic primary mirror and a flat secondary mirror, called Newtonian reflectors.

This telescope design offers the best bang for the buck in terms of aperture-for-dollars-spent, and, in the minds of most amateur astronomers, aperture rules. All other things being equal, a larger scope will outperform a smaller scope.

So why aren't reflectors the only telescope design today? First, they tend to be larger than the

other designs, so not everyone has the space to store them or the ability to transport them.

Manufacturers have devised ways to deal with large reflectors. One way is by replacing the solid tube with removable trusses. This breaks the scope down into manageable parts, with the box containing the primary mirror being the heaviest.

Reflector owners also have to become well-versed in the art of collimation (alignment of the optical parts). While not difficult, it does add time to the setup. Additionally, the mirrors' reflective coatings will decay over the years, and, eventually, owners will need to have the optics recoated.

Anttlers Optics 10-inch HPN

Got a hankering for top-of-the-line optics with lots of bells and whistles but don't want to pay premium prices? Anttlers Optics caters to your needs with the High Performance Newtonian (HPN) series.

Scott Anttler upgrades a standard Antares/GSO Dobsonian-mounted reflector. When he's done, you'll have a telescope with a high-quality primary mirror, a smaller secondary mirror (which improves contrast), internal flocking (to reduce scattered light), one of several different active cooling options, and other tweaks to enhance your viewing pleasure.

Anttlers Optics will also work directly with you to meet your specific needs. And the best part is the price. The 10-inch HPN costs a mere \$1,099.



Parks Optical Astrolight AZ-6

Parks Optical designed its new Astrolight line of Newtonian reflectors (which also includes an 8-inch version, the AZ-8) as an alt-azimuth system. Unlike many other manufacturers, however, rather than design a Dobsonian mount, they chose to employ a pier system. And Parks Optical made it light and compact. The optical-tube assembly weighs in at only 12 pounds (5.4 kg); the mount adds 25 pounds (11.4 kg).

The AZ-6 is easy to set up. Within a few minutes of arriving at my dark-sky site, I was observing. Although lightweight, the rolled-steel pier provides a solid base. The secondary mirror blocks a minuscule 7 percent of the incoming light from the primary mirror. (The AZ-8's secondary-mirror obstruction measures only 5 percent.)



Celestron StarHopper 8

There's something to be said for the basic Dobsonian mount design. I spent many years under the stars with one of the early mass-produced Dobs, and the StarHopper 8 shows how far entry-level scopes have come in the last decade.

This instrument gives you maximum aperture for minimum expenditure. With a 2" focuser, 25mm Plössl eyepiece, and an 8x50 finder scope, you'll be ready to go the first night.

Don't worry about counterweights. The StarHopper 8 sports a variable-tension system in both its altitude and azimuth axes, so you can get those motions just right. This 8-inch scope offers enough aperture to keep you busy for a lifetime.



Meade 12-inch LightBridge

Until recently, if you wanted a truss-tube scope, you had to pay top dollar or make it yourself. As the first manufacturer to mass-produce truss-tube Dobs, Meade deserves praise for its LightBridge line.

Meade offers LightBridges in 8-, 10-, and 12-inch sizes, and Meade promises the 16-inch will be arriving soon. Out of the current line, the 12-inch is my hands-down favorite.

While a 12-inch aperture creates a large telescope, the LightBridge's 6-pole truss design lets you easily break down the scope for storage and transport. Each LightBridge Dob comes with a reflex finder, a 2" Crayford-style focuser, a mirror-cooling fan, and Meade's 26mm QX eyepiece.

Orion StarBlast

A while back, a friend asked me what telescope he should buy for his young daughter. She had an interest in astronomy, and, while he wanted to encourage that, he couldn't afford to drop an arm and a leg on what could be a passing interest.

Enter Orion's StarBlast. This 4.5-inch f/4 Dobsonian-mounted reflecting telescope has won a place in the heart of anyone who has used it. It's small, portable, and gives great views, too.

It's a good choice for small children or as a second scope for traveling or camping. At home, set it on the bookshelf in your den, where it will be ready to go at a moment's notice.

Orion thoughtfully provides two eyepieces that yield 26x and 75x. User response has been so good that Orion has launched a version of the OTA optimized for imaging.



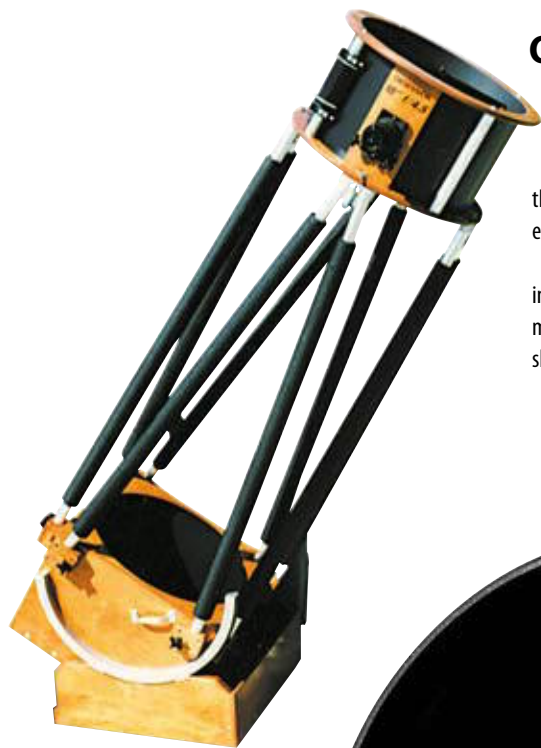
JMI Telescopes RB-10

If you're a binocular addict, JMI's RB-10 is a little slice of heaven just for you. One of JMI's Reverse Binocular series, this 10-inch model has serious aperture. Nonetheless, it's small enough to be transported with a bit of effort. This binocular telescope comprises a pair of 10-inch Newtonian reflectors mounted on a portable pier. JMI designed it as reverse binoculars, with the telescopes pointing over your shoulders. The RB-10 sports dual 2" motorized focusers, a handle-bar, and a set of wheels. It's also compatible with Digital Setting Circles (DSC) to make finding celestial objects easier.

Obsession Telescopes 18-inch

There's just no substitute for aperture. If you've got the space and the cash, there's nothing — repeat, nothing — quite like viewing through a big "light-bucket." For my money, the 18-inch f/4.5 Obsession truss-tube Dobsonian is a superb large telescope. It's big enough to give you the feeling that anything is possible, but small enough for one person to handle. As another benefit, most people won't even need a ladder because of the compact construction.

Obsession offers a choice of primary-mirror manufacturers and a host of other options, including go-to and tracking capabilities. Enhanced coatings on all Obsession mirrors ensure that as much light gets to your eye as possible. Best of all, Obsession's delivery times are among the shortest in the industry — often only 1 or 2 months.



Orion SkyQuest XT10 IntelliScope

Orion offers a classic 10-inch solid-tube Dobsonian-mounted Newtonian telescope, but with a twist. The IntelliScope line is the only series of inexpensive, mass-produced Dobs that comes with Digital Setting Circles factory installed. The Object Locator guides the user to targets in the NGC, IC, and Messier catalogs, along with hundreds of single, multiple, and variable stars.

Orion's IntelliScope comes with a 2" focuser, 1¼" adapter, eyepiece rack, 9x50 right-angle finder scope, two Sirius Plössl eyepieces, a bracket for the SkyQuest Object Locator, and a laser collimator. You also have the option of a basic package without Orion's Object Locator (which can be added later).

Plettstone 15-inch

Plettstone designs its custom truss-tube telescopes for amateurs who want lots of aperture combined with good portability. The design takes a minimalist approach, which features a three-pole truss and a single ring for the upper truss assembly. The savings in both size and weight are significant and allow the owner to pack a large scope into a small space. This scope also assembles, or disassembles, easily.

You can choose mirrors from Pegasus, Stevens, or Zambuto and the Argo Navis and/or ServoCat system(s) for the ultimate in go-to and tracking. The 15-inch f/4.5 version allows most users to observe objects high in the sky while standing, so you won't have to pack a stool or ladder.

Plettstone Dobs do not come with light shrouds, nor does the three-pole design lend itself to them. This makes the telescopes prone to scattered light and dew formation on the primary mirrors.



Starmaster Versa 8

Are you looking for one "do-it-all" telescope? Starmaster introduced its Versa series to address the needs of many amateur astronomers. The 8-inch model is my favorite.

This lightweight telescope breaks down for easy portability and assembles with only a Phillips screwdriver. It has two mounting options: standard Dobsonian or German equatorial.

Because of the Zambuto primary mirror and small 1.52-inch secondary mirror, deep-sky and planetary views are superb. Standard features include a 2" Feathertouch focuser, counterweight system, mounting rings, secondary-mirror heater, and more. Options include a two-piece travel-truss system for airline travel, an alt-azimuth rocker base, and Sky Commander Digital Setting Circles.



Takahashi Mewlon 210

Takahashi introduced its Mewlon 210 for advanced amateurs looking for a telescope with a slow focal ratio. This scope employs a Dall-Kirkham design, a Cassegrain variant that uses a concave, ellipsoid primary mirror in conjunction with a convex spherical secondary mirror.

The advantage with this design is that the optics are easier to produce than with other designs. In theory, this comes at the expense of additional image distortions. But, ultimately, it comes down to the views. Just ask those who have looked or photographed through a Mewlon if it's worth it, and they'll give you a resounding "yes."

Vixen R200SS

Vixen aimed its R200SS to astrophotographers wanting to gather lots of light and still capture wide fields of view. This scope offers 8 inches of aperture at a fast f/4.

The R200SS uses a 60mm rack-and-pinion drawtube to cover a field that measures 2.6° by 1.7° on a 35mm film frame. Weighing in at a mere 11.7 pounds (5.3 kg), and measuring only 28 inches (711mm) long, the scope works well on medium-sized German equatorial mounts (sold separately). Less weight and bulk means more stability — and that's always a point in a telescope's favor.

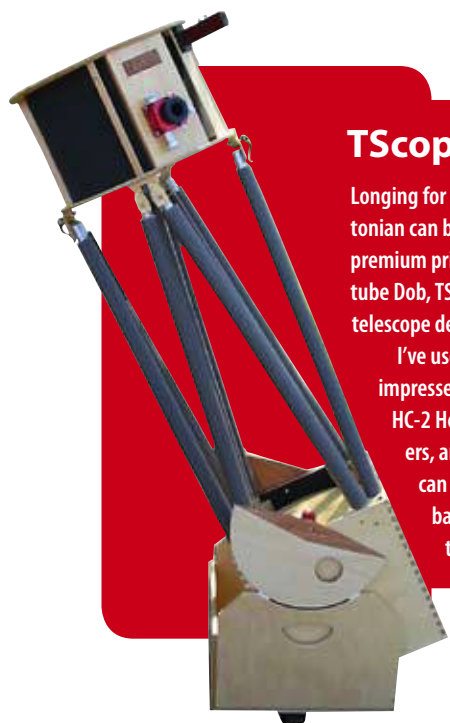
TSopes 14-inch

Longing for the views only a big Dobsonian-mounted Newtonian can bring? Need transportability, but can't pay a premium price? Starting at only \$2,595 for a 14-inch truss-tube Dob, TSopes offers what has to be one of the best telescope deals in astronomy today.

I've used several of these and walked away impressed each time. The scopes come with Kineoptics HC-2 Helical Crayford-style focusers, Rigel Quick Finders, and Obsidian Optics primary mirrors. TSopes can also install its own go-to drive. The only drawback? These scopes are so popular that delivery times can be lengthy.

REFLECTOR COMPARISON

Manufacturer/Model	Aperture	f/ratio	Mount/tripod included?	Price
Anttlers Optics 10-inch HPN	10.0" (252mm)	4.8	Yes	\$1,099
Celestron StarHopper 8	8.0" (202mm)	6	Yes	349
JMI Telescopes RB-10	10.0" (252mm)	4.7	Yes	5,495
Meade 12-inch LightBridge	12.0" (302mm)	5	Yes	999
Obsession Telescopes 18-inch	18.0" (454mm)	4.5	Yes	5,695
Orion StarBlast	4.5" (113mm)	4	Yes	179
Orion SkyQuest XT10 IntelliScope	10.0" (252mm)	4.7	Yes	789
Parks Optical AZ-6	6.0" (152mm)	6	Yes	799
Plettstone 15-inch	15.0" (378mm)	4.5	Yes	5,885
Starmaster Versa 8	8.0" (202mm)	5.6	No	2,895
Takahashi Mewlon 210	8.3" (210mm)	11.5	No	3,095
TSopes 14-inch	14.0" (353mm)	4.7	Yes	2,595
Vixen R200SS	8.0" (202mm)	4	No	1,499



Compound telescopes

Compound, or catadioptric, telescopes incorporate various hybrid designs that use both lenses and mirrors to collect and focus light. Several types are in production today. The most popular compound telescope is the Schmidt-Cassegrain telescope, better known as the SCT. You'll also find Maksutov-Cassegrains (Mak-Cass), Maksutov-Newtonians (Mak-Newt), and Schmidt-Newtonians (Schmidt-Newt).

These compact scopes let you observe from a seated position, especially when they're attached to a motor-driven alt-azimuth mount. Gadget-lovers will find more add-ons and accessories for compound scopes than any other type, both from major manufacturers and third-party companies. Some options provide rapid cooling, dew prevention, and motorized focusing; others allow you to turn the scope into a wide-field imaging platform.

Celestron C8 SGT

For the individual interested in a telescope-mount combo, Celestron's C8 SGT is one of the best packages on the market. Your bucks not only buy you Celestron's 8-inch Schmidt-Cassegrain telescope, you'll also get the respected ASGT computerized mount. The C8 itself has long been the workhorse product in Celestron's lineup — and for good reason. Eight inches of aperture is significant in terms of light-gathering power and resolution, but the OTA is small and lightweight. That makes it easy to handle and a perfect match for the mount. The ASGT comes equipped with the NexStar go-to system. The nature of the German equatorial mount allows you to mount other OTAs, which is a big plus for this package.



Celestron CPC 1100 GPS

The CPC 1100 is Celestron's 11-inch fork-mounted Schmidt-Cassegrain telescope. Celestron designed this 2,800mm-focal-length scope for those observers wishing to go deep, stay somewhat portable, and observe from a seated position.

The CPC features a 16-channel GPS for a no-guesswork setup. Celestron's patented SkyAlign and the NexStar hand-controller puts 45,000 celestial targets within reach.



Celestron NexStar 6 SE

Celestron made its NexStar 6 SE an easily transportable telescope. This 6-inch SCT, mounted on a one-arm fork mount, weighs in at a mere 30 pounds (13.6 kg), including tripod. This makes it a good choice for observers seeking a grab-and-go setup.

For years, Celestron's 5-inch model has been the undiscovered gem in its SCT line. The 6-inch model continues that tradition while offering 20-percent greater resolution and 44-percent more light-grasp. The OTA and mount connect via a one-knob, quick-release system that allows for easy field assembly.





Intes Micro Alter MN65

Intes offers a telescope for advanced amateur astronomers looking for exceptional do-it-all optics at a good price — the Intes Micro Alter MN 65. This telescope sports 6.5 inches of aperture and an f/5.5 Maksutov-Newtonian design.

The small secondary mirror doesn't obstruct much light, so this scope provides spectacular, high-contrast views of the Moon and planets. The short focal ratio allows the observer to go "wide" and pull in those low-power views of large deep-sky objects.

These scopes are well-known for their ability to keep up with apochromats of similar aperture. The ones I've used have provided some stunning views at both high and low powers.

Meade 14-inch RCX400

If you have an observatory, Meade may have created your dream telescope. Meade took one of the world's most advanced optical-tube assemblies and mated it to an equally advanced drive system powered by the AutoStar II computer to produce the RCX400 package.

Meade manufactures the RCX400's OTA out of Kevlar and carbon fiber to minimize expansion. The RCX400 offers electronic focusing of the secondary mirror to reduce image shift.

A dew heater is built in, and you collimate electronically via the AutoStar II. Most importantly, the optics produce a sharp, flat field of view excellent for astrophotography. This telescope is well-made, powerful, and easy to use.



Meade ETX-90PE

If you're looking for a high-performance scope in a smaller package, consider Meade's ETX-90PE. Meade introduced the AutoStar go-to system with this little scope several years back and changed the face of amateur astronomy.

This 3.6-inch f/13.8 Maksutov-Cassegrain telescope uses Meade's latest *AutoStar* software and makes an excellent instrument for lunar, planetary, and double-star observing.

The AutoStar system makes finding your targets easy — especially with the automatic alignment routine and the included single-power finder.

For those who observe on the spur of the moment, AutoStar's "Tonight's Best" tour can make the most of your sessions. Meade also includes a computer cable that allows for AutoStar updates.



Meade 10-inch LX90GPS

Meade's 10-inch LX90GPS is a sophisticated, yet affordable, package that gives you all the features offered by the AutoStar controller. This serious aperture pulls in "faint fuzzies" and will give you pleasing views of the Moon and planets. Moreover, fork-mounted SCTs are comfortable instruments that allow easy access to the eyepiece from nearly all viewing positions.

Go-to equipped SCTs are also good instruments for gadget lovers. You'll find more accessories available for these than any other type of scope. This is a big system, though, and not easy to transport. If you travel frequently to a dark site, make sure you can handle this telescope by yourself.



Orion SkyView Pro 150 Maksutov-Cassegrain

The SkyView Pro 150 is a 6-inch Maksutov-Cassegrain telescope. This variant of the Cassegrain design uses a front corrector lens curved in a meniscus shape. The Mak-Cass is well-regarded among lunar and planetary observers for the high-contrast, high-resolution images it delivers.

This version from Orion has an 1,800mm focal length (f/12) and comes with the popular SkyView Pro mount (available with or without go-to). Orion also includes a prism star diagonal, a 26mm Plössl eyepiece, and an 8x40 finder scope. The SkyView Pro 150 is an excellent tool for the intermediate to advanced amateur interested in busting globulars, picking off double stars, and obtaining detailed glimpses of the Moon and planets.



COMPOUND TELESCOPE COMPARISON

Manufacturer/Model	Aperture	f/ratio	Mount/tripod included?	Price
Celestron C8 SGT	8" (202mm)	10	Yes	\$1,514
Celestron NexStar 6 SE	6" (151mm)	10	Yes	999
Celestron CPC 1100 GPS	11" (277mm)	10	Yes	2,799
Intes Micro Alter MN65	6.5" (164mm)	5.5	No	1,750
Meade RCX400	14" (353mm)	8	Yes	9,599
Meade ETX-90 PE	3.6" (91mm)	13.8	Yes	699
Meade LX90GPS	10" (252mm)	10	Yes	2,699
Orion SkyView Pro 150	6" (151mm)	12	Yes	919